Quantifying Carbon Footprint Reduction Opportunities of US Households and Communities

DOE Workshop on Energy Efficiency Potential:
June 13, 2016

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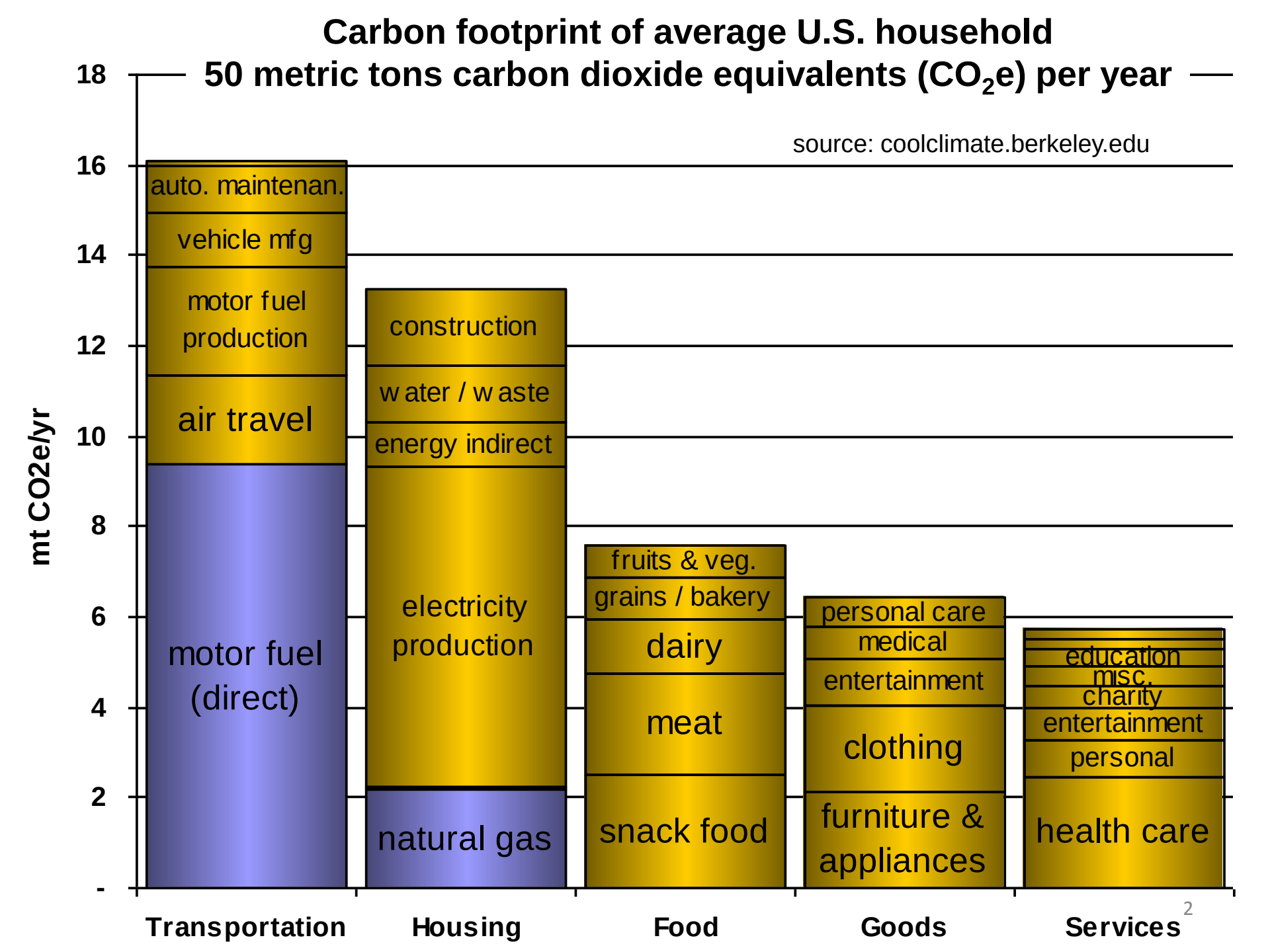
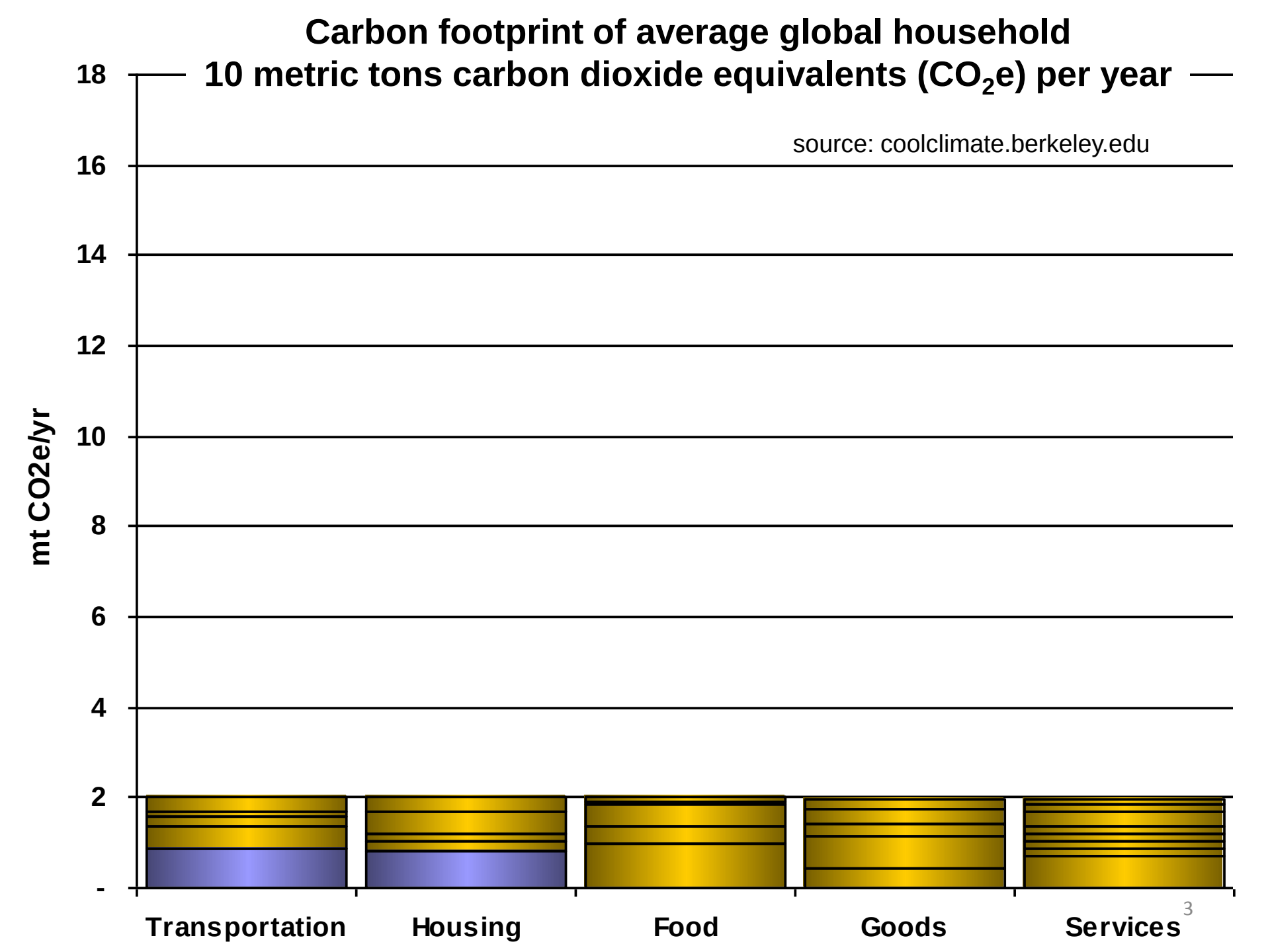
Program Director
CoolClimate Network, UC Berkeley

CoolClimate Network

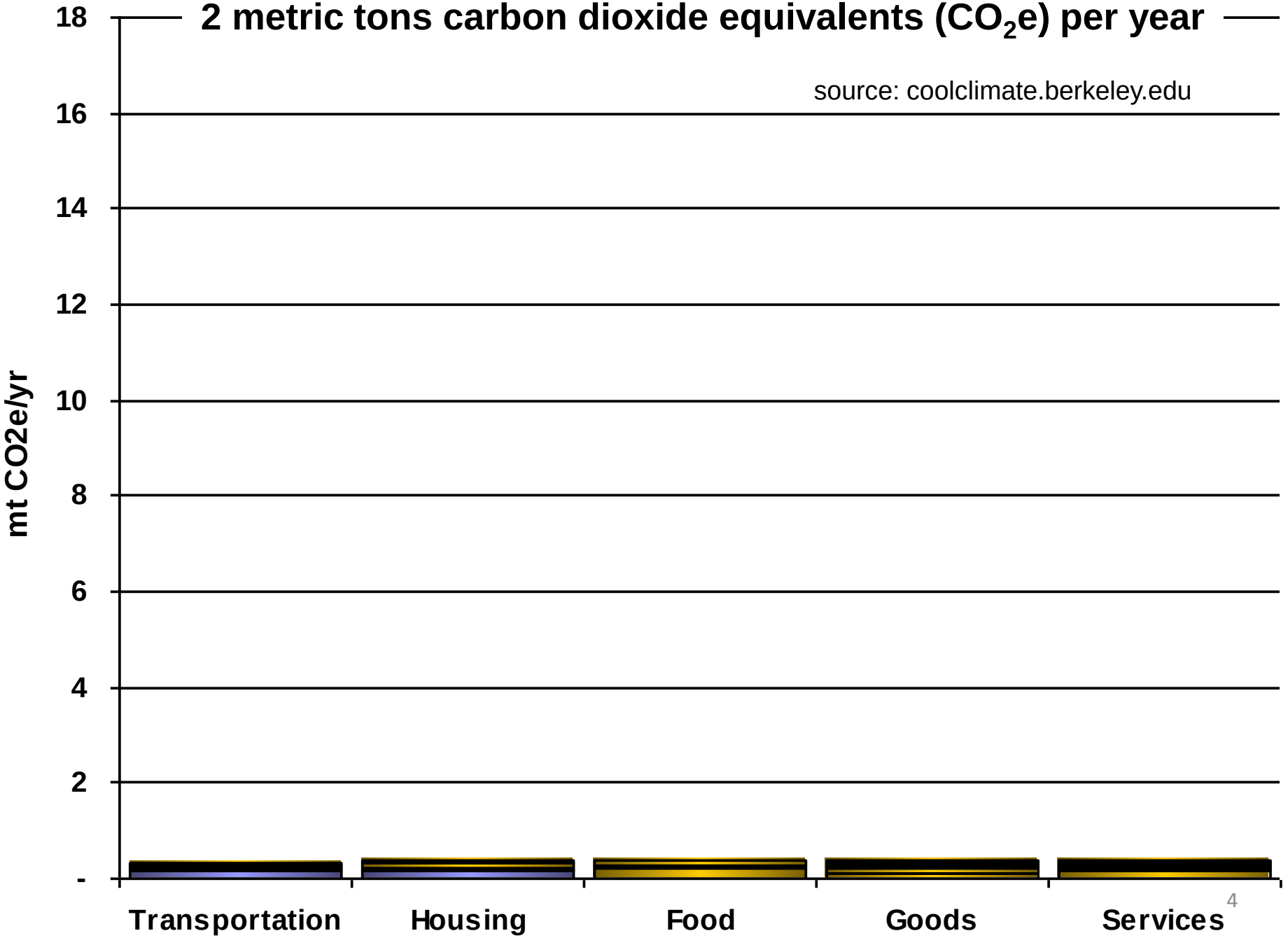
University of California RAEL Renewable & Appropriate Energy Laboratory

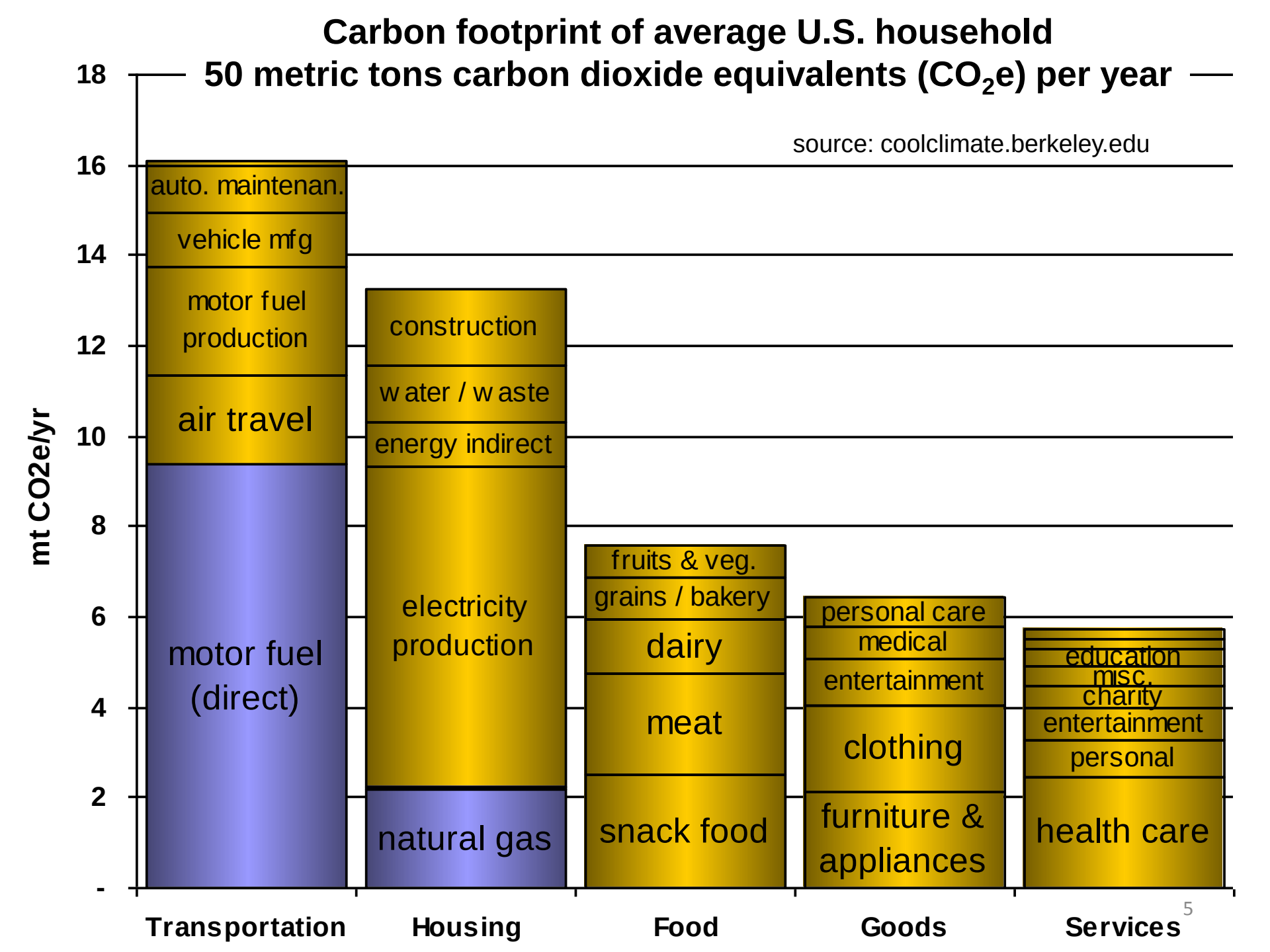
CoolCalifornia.org Simple steps for a sustainable future


Carbon footprint of average U.S. household
50 metric tons carbon dioxide equivalents (CO_2e) per year
source: coolclimate.berkeley.edu
mt CO2e/yr
18
16
14
12
10
8
6
4
2
-
auto. maintenan.
vehicle mfg
motor fuel production
air travel
motor fuel (direct)
construction
water / waste
energy indirect
electricity production
natural gas
fruits & veg.
grains / bakery
dairy
meat
snack food
personal care
medical
entertainment
clothing
furniture & appliances
education
misc.
charity
entertainment
personal
health care
Transportation
Housing
Food
Goods
Services
2


Carbon footprint of average global household
10 metric tons carbon dioxide equivalents (CO_2e) per year
source: coolclimate.berkeley.edu
mt CO2e/yr
18
16
14
12
10
8
6
4
2
-
Transportation
Housing
Food
Goods
Services

Average global household under climate stabilization
2 metric tons carbon dioxide equivalents (CO_2e) per year

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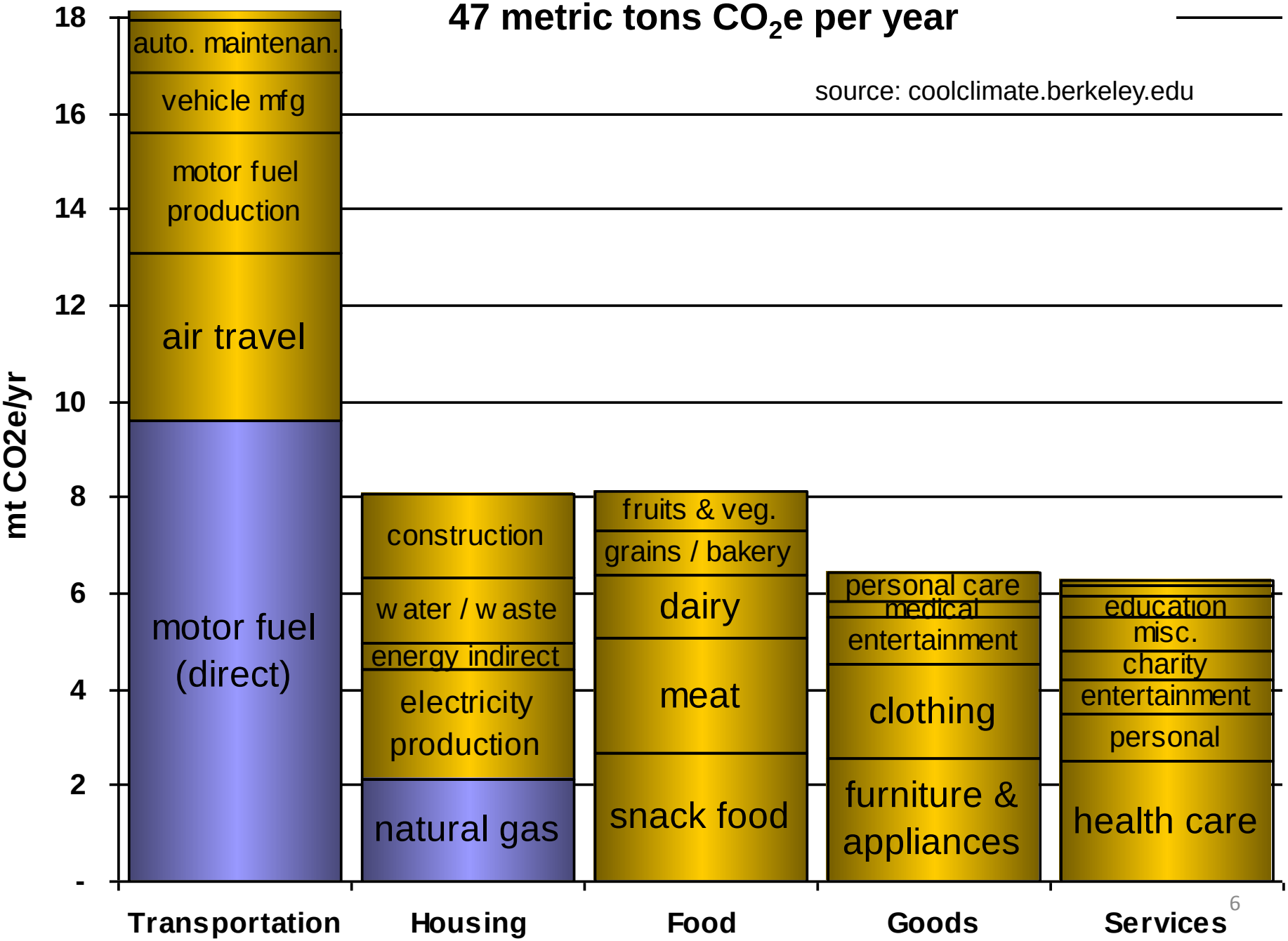
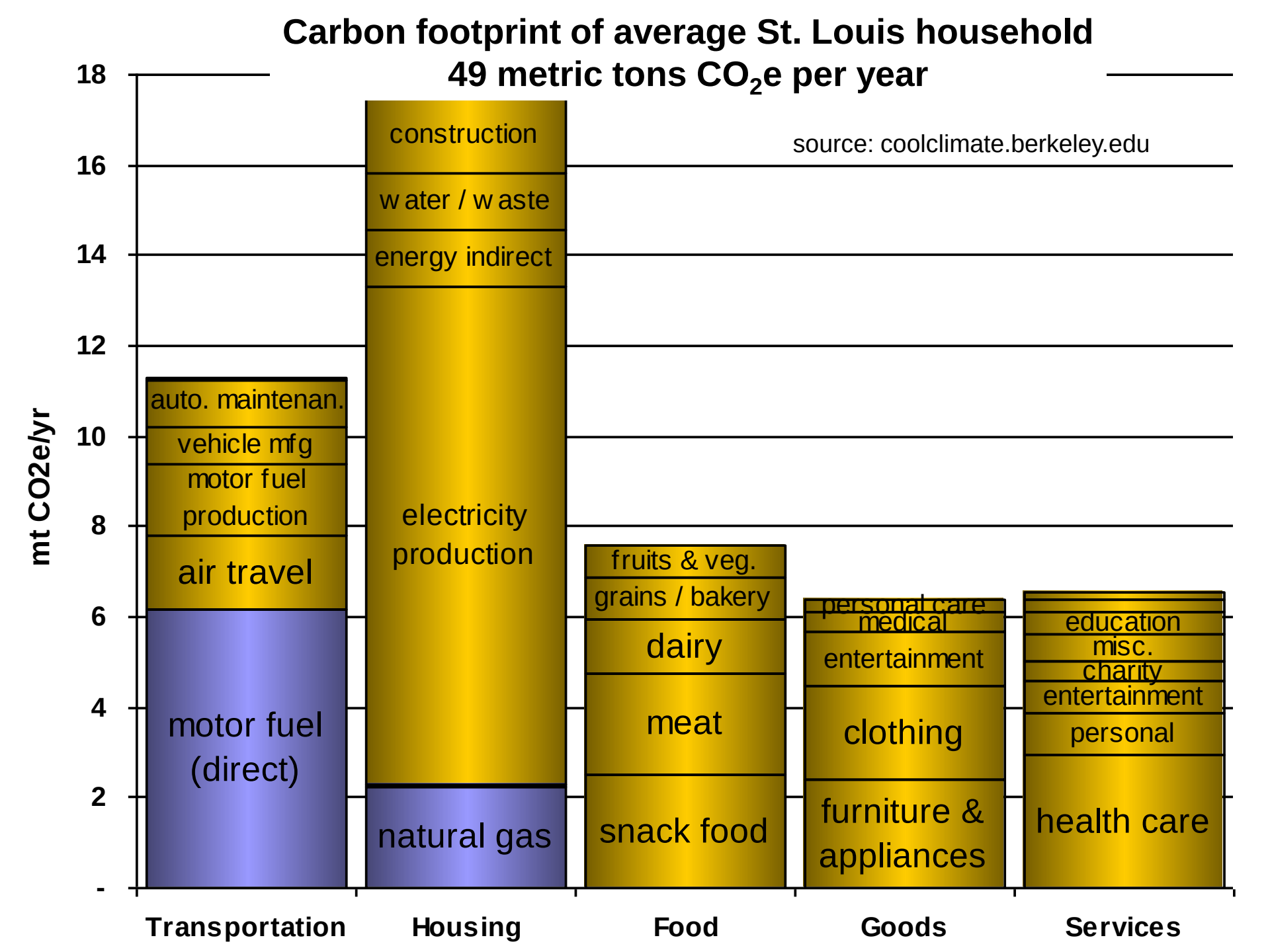
auto. maintenan.
vehicle mfg
motor fuel production
air travel
motor fuel (direct)
construction
water / waste
energy indirect
electricity production
natural gas
fruits & veg.
grains / bakery
dairy
meat
snack food
personal care
medical
entertainment
clothing
furniture & appliances
education
misc.
charity
entertainment
personal
health care
Transportation
Housing
Food
Goods
Services

Carbon footprint of average California household
47 metric tons CO_2e per year




Carbon footprint of average St. Louis household
49 metric tons CO2e per year
source: coolclimate.berkeley.edu
mt CO2e/yr
18
16
14
12
10
8
6
4
2
-
auto. maintenan.
vehicle mfg
motor fuel production
air travel
motor fuel (direct)
construction
water / waste
energy indirect
electricity production
natural gas
fruits & veg.
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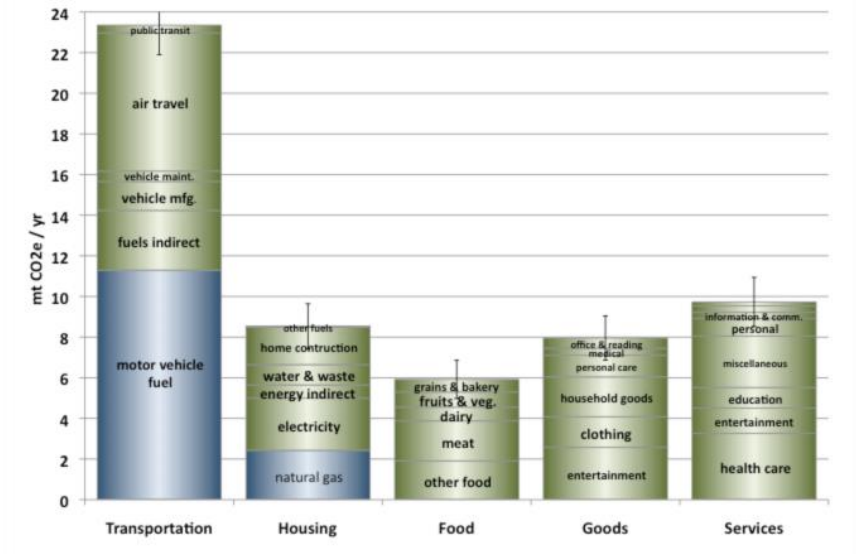
dairy
meat
snack food
personal care
medical
entertainment
clothing
furniture & appliances
education
misc.
charity
entertainment
personal
health care
Transportation
Housing
Food
Goods
Services

Figure 6

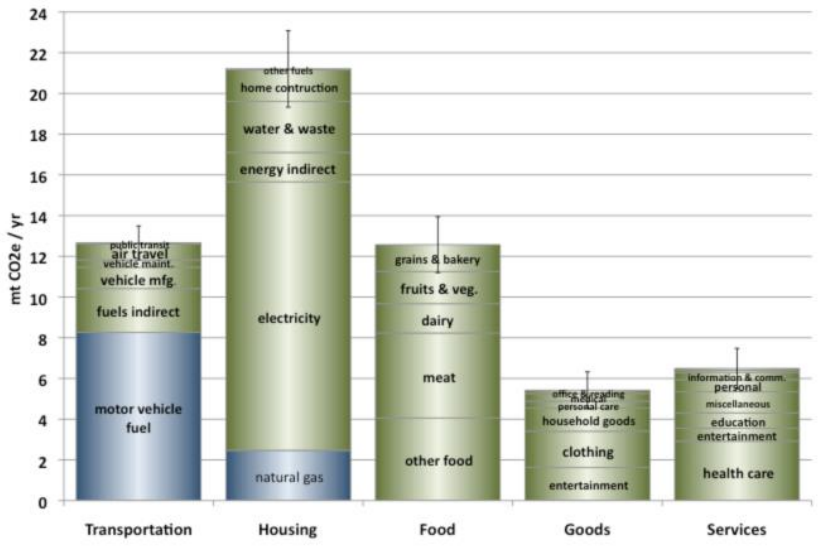
Household A Carbon Footprint

2-person $90k household in San Francisco

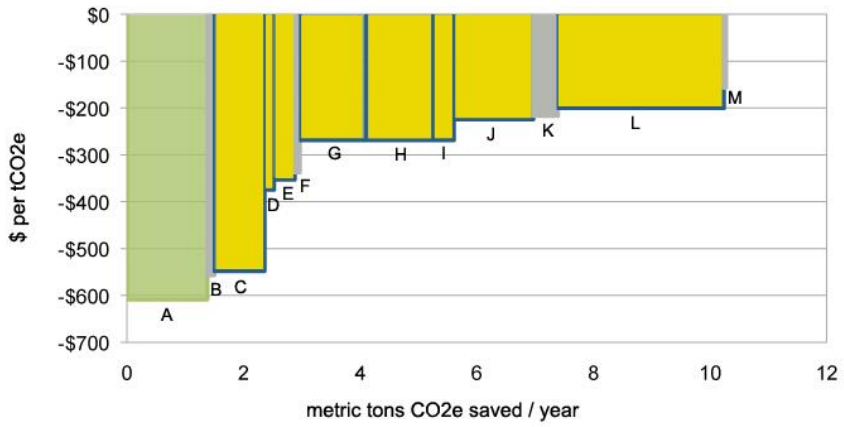


Household B Carbon Footprint

5-person $45k household in St. Louis

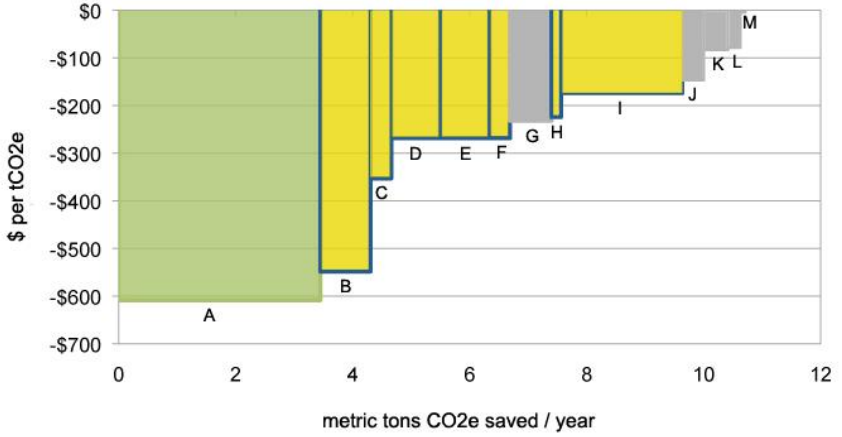


Household A GHG Abatement Cost Curve



A - Change diet
B - Telecommute
C - Take transit
D - Eco-driving
E - Maintain vehicles
F - Ride bike
G - Turn up thermostat
H - Turn down thermostat
I - Reduce flying
J - Trade in vehicles
K - Buy CFLs
L - Line-dry clothes
M - Energy Star fridge

Household B GHG Abatement Cost Curve



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B - Telecommute
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I - Reduce flying
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K - Buy CFLs
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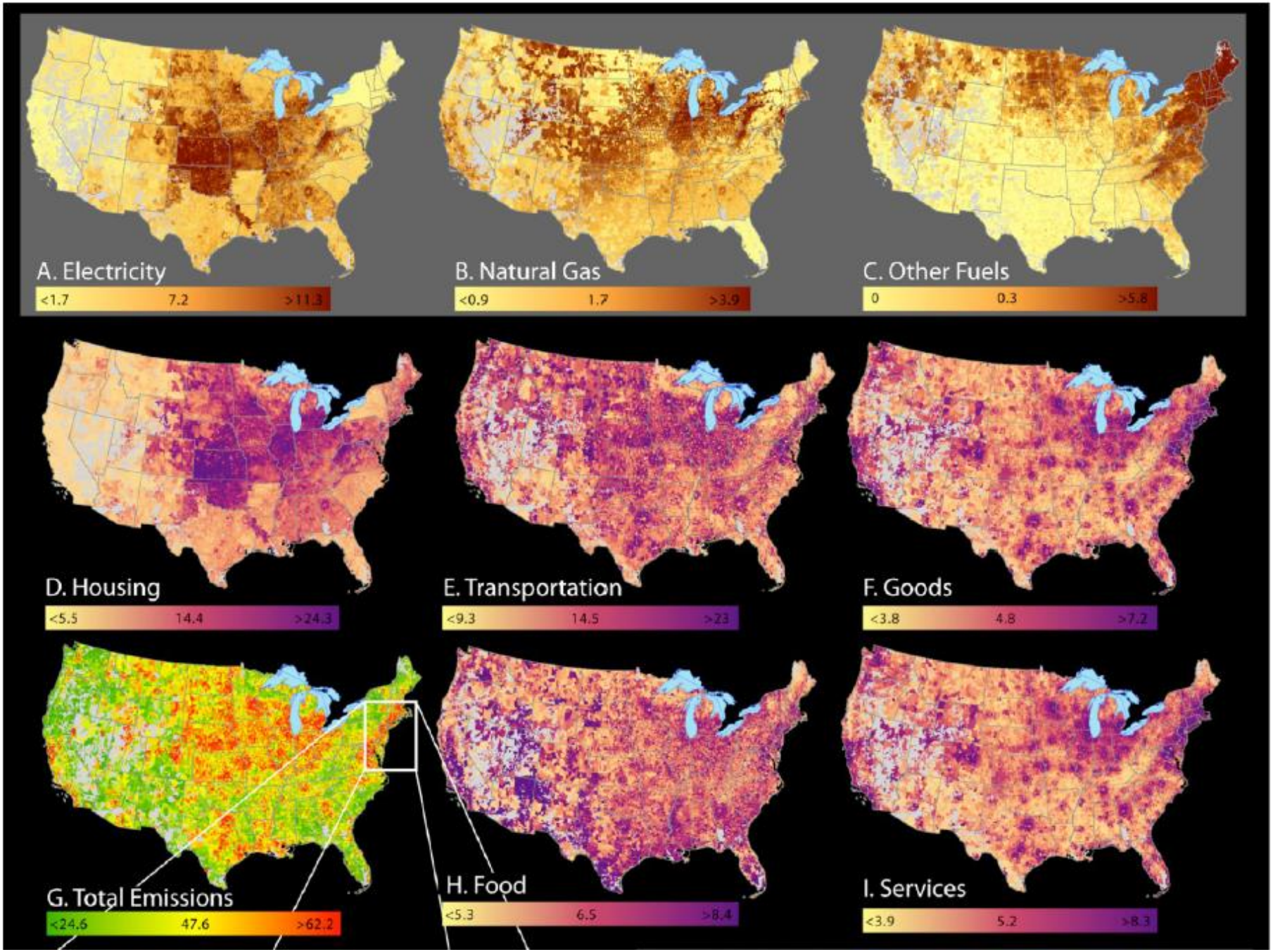
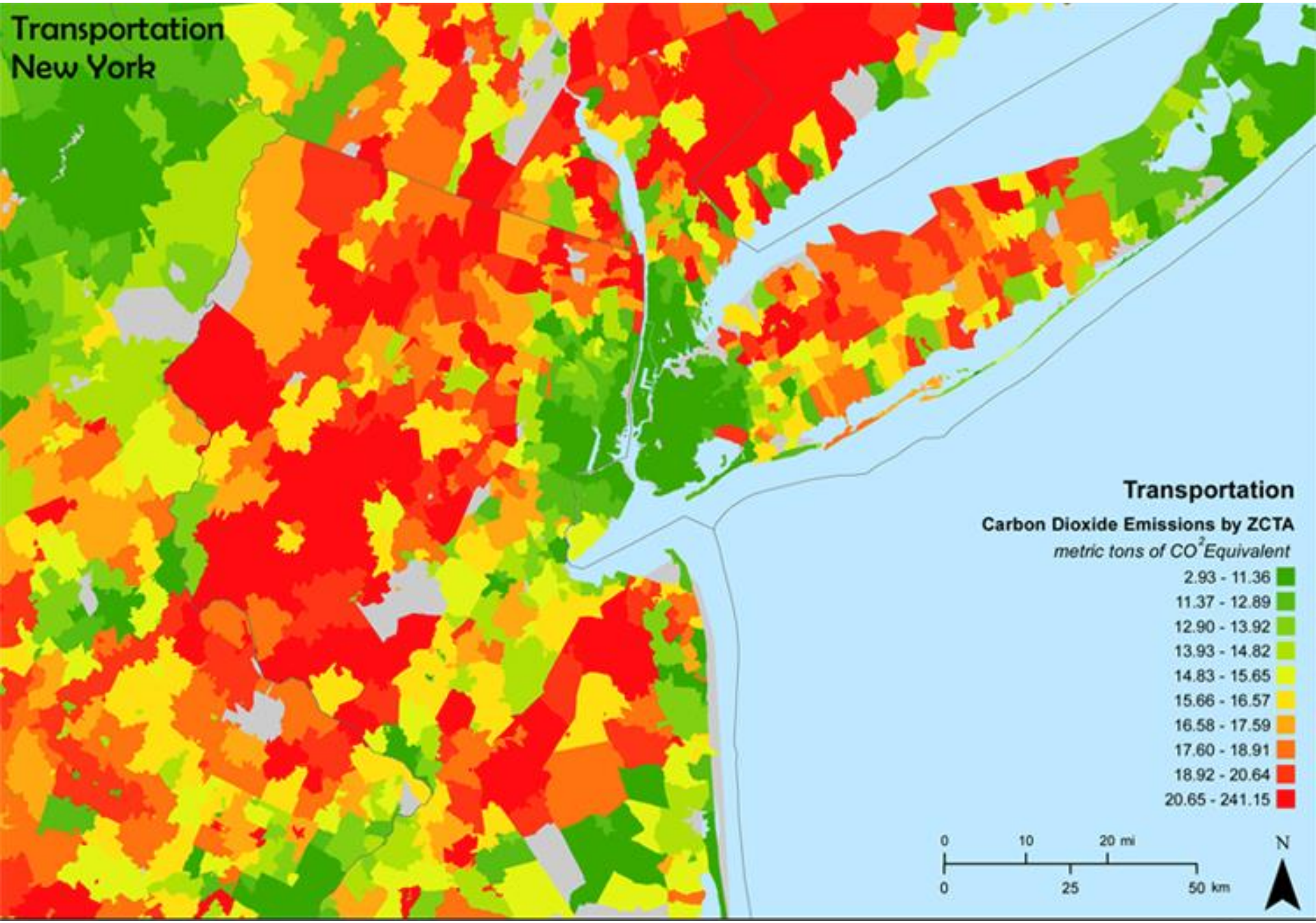
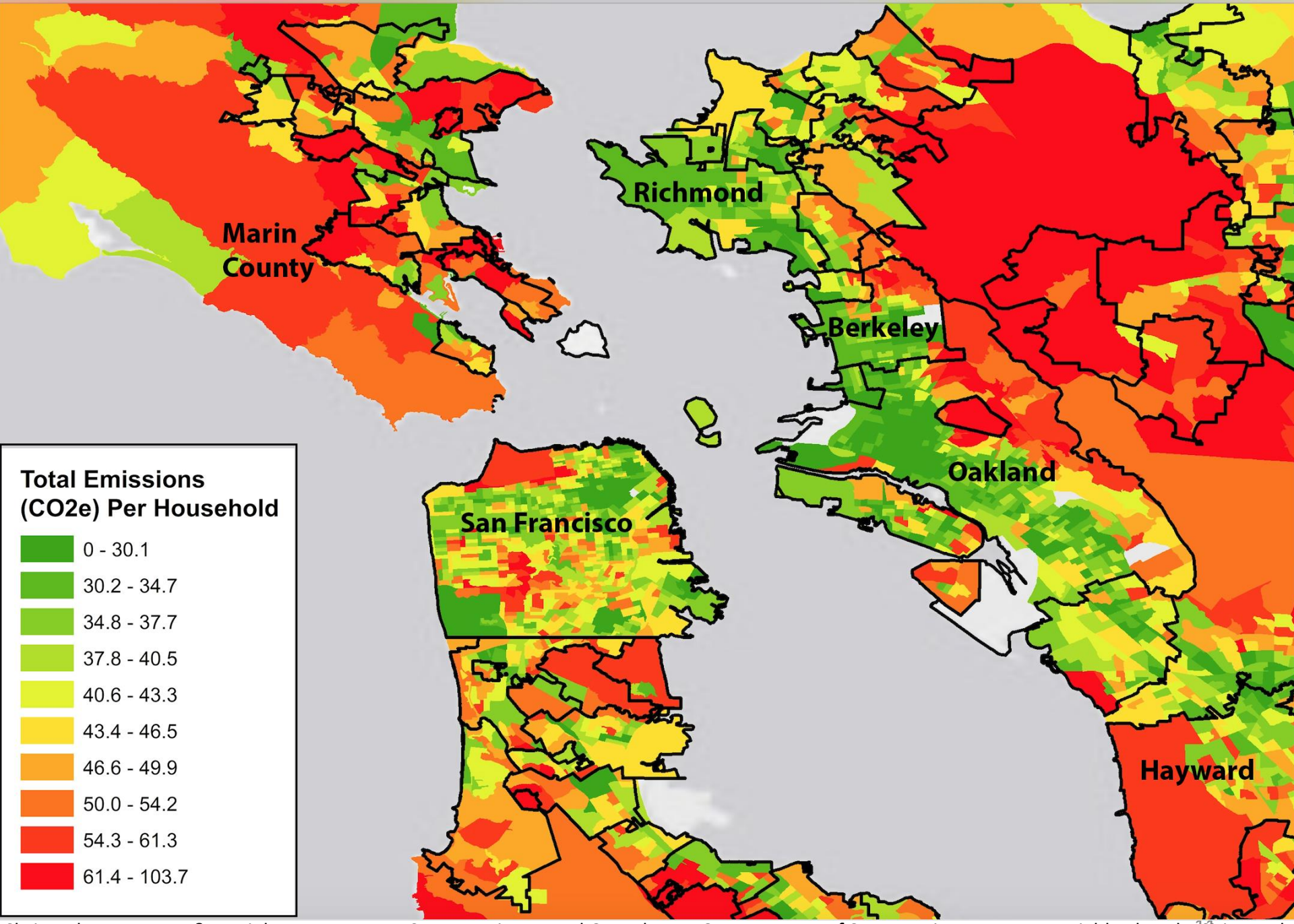
M - Energy Star fridge

Christopher M. Jones and Daniel M. Kammen, Quantifying Carbon Footprint Reduction Opportunities for U.S. Households and Communities. Environ. Sci. Technol., 2011, 45 (9), pp 4088–4095



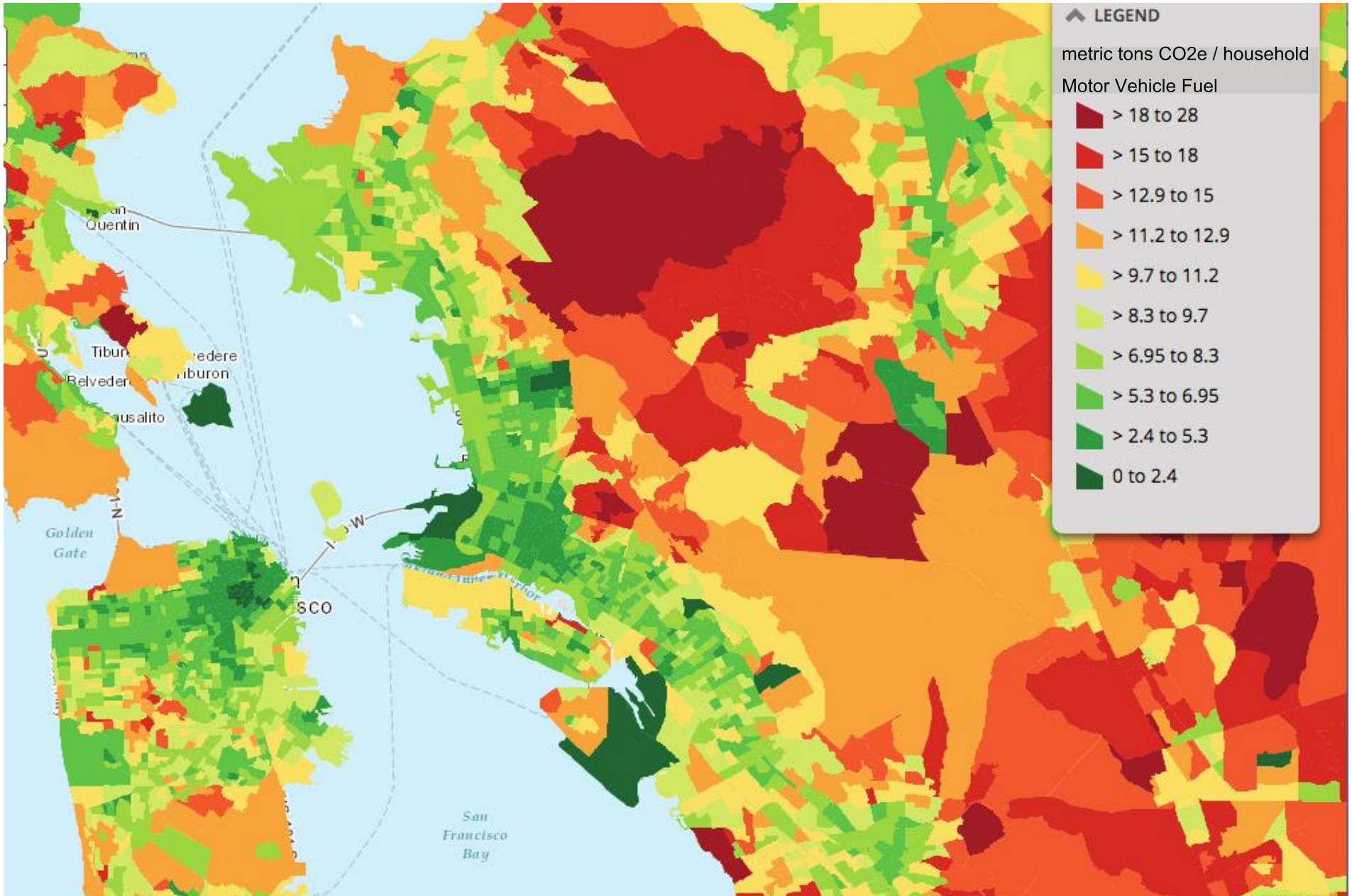
Christopher M. Jones and Daniel M. Kammen, Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density. Environ. Sci. Technol., 2014, 48 (2), pp 895–902.

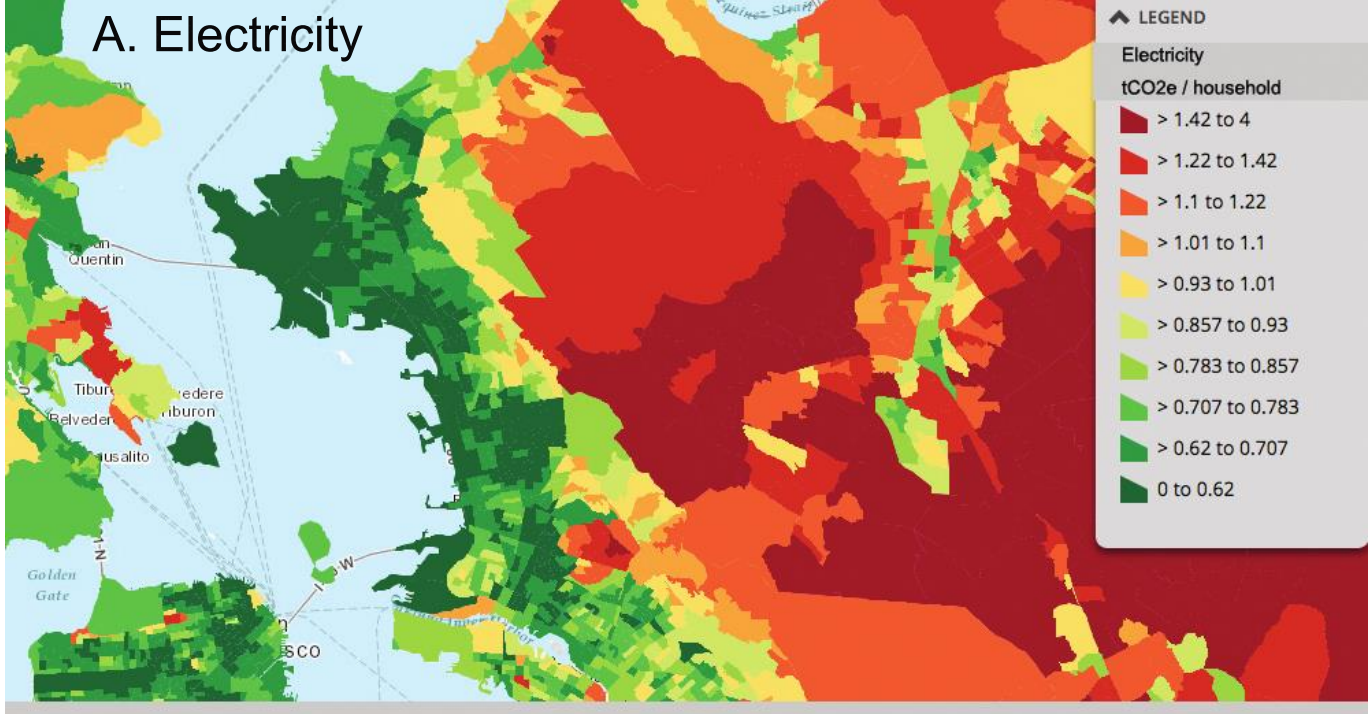

Transportation
New York
Transportation
Carbon Dioxide Emissions by ZCTA
metric tons of CO^2 Equivalent
2.93 - 11.36
11.37 - 12.89
12.90 - 13.92
13.93 - 14.82
14.83 - 15.65
15.66 - 16.57
16.58 - 17.59
17.60 - 18.91
18.92 - 20.64
20.65 - 241.15
0
10
20 mi
0
25
50 km
N

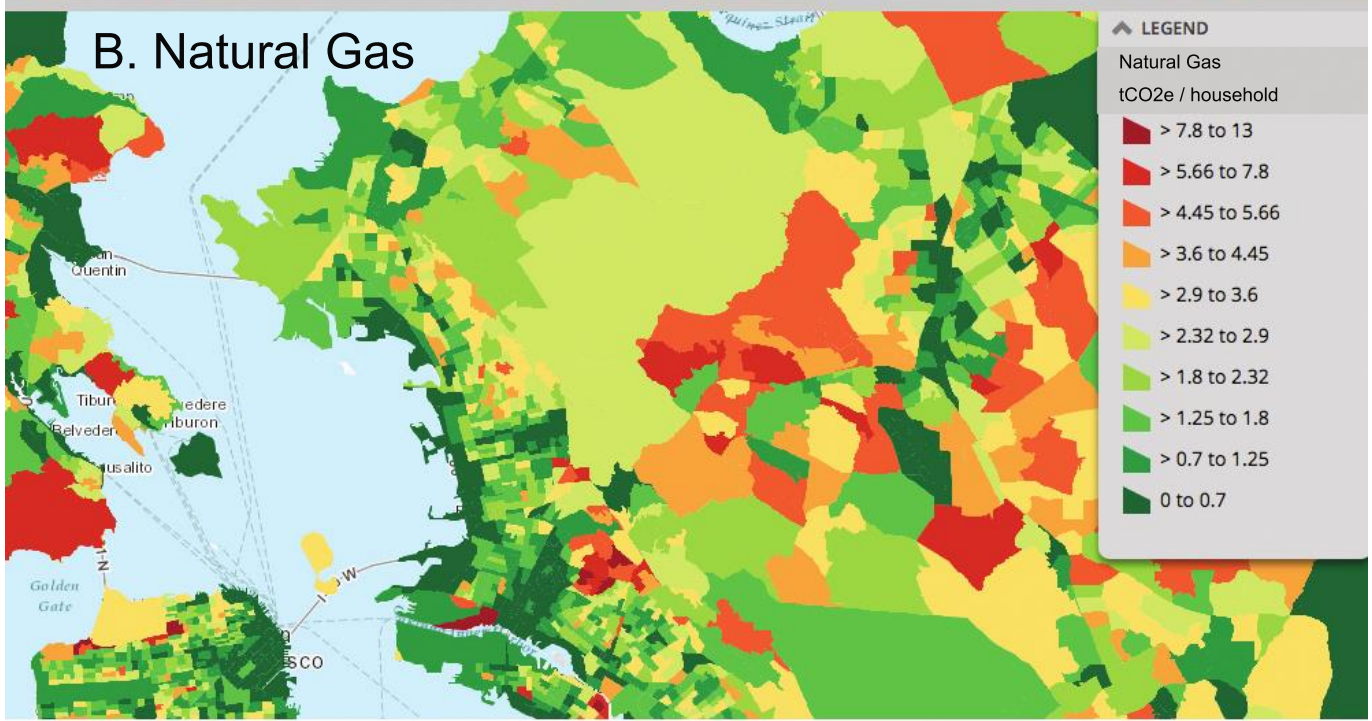


Christopher M. Jones & Daniel M. Kammen. A Consumption-Based Greenhouse Gas Inventory of San Francisco Bay Area Neighborhoods, Cities and Counties: Prioritizing Climate Action for Different Locations. Report prepared for the Bay Area Air Quality Management District. December 15, 2015

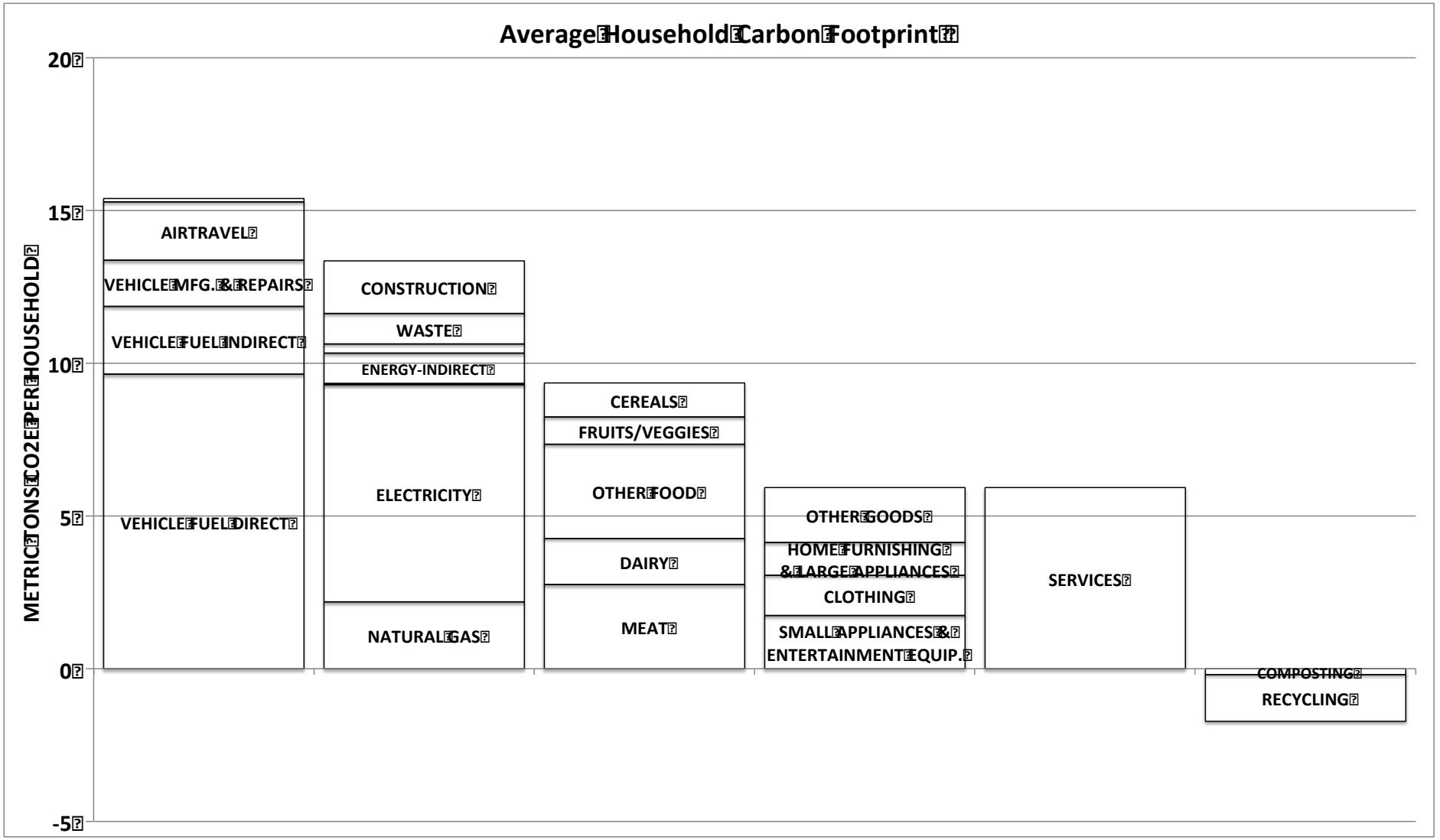
Household GHG Emissions from Transportation by Block Group



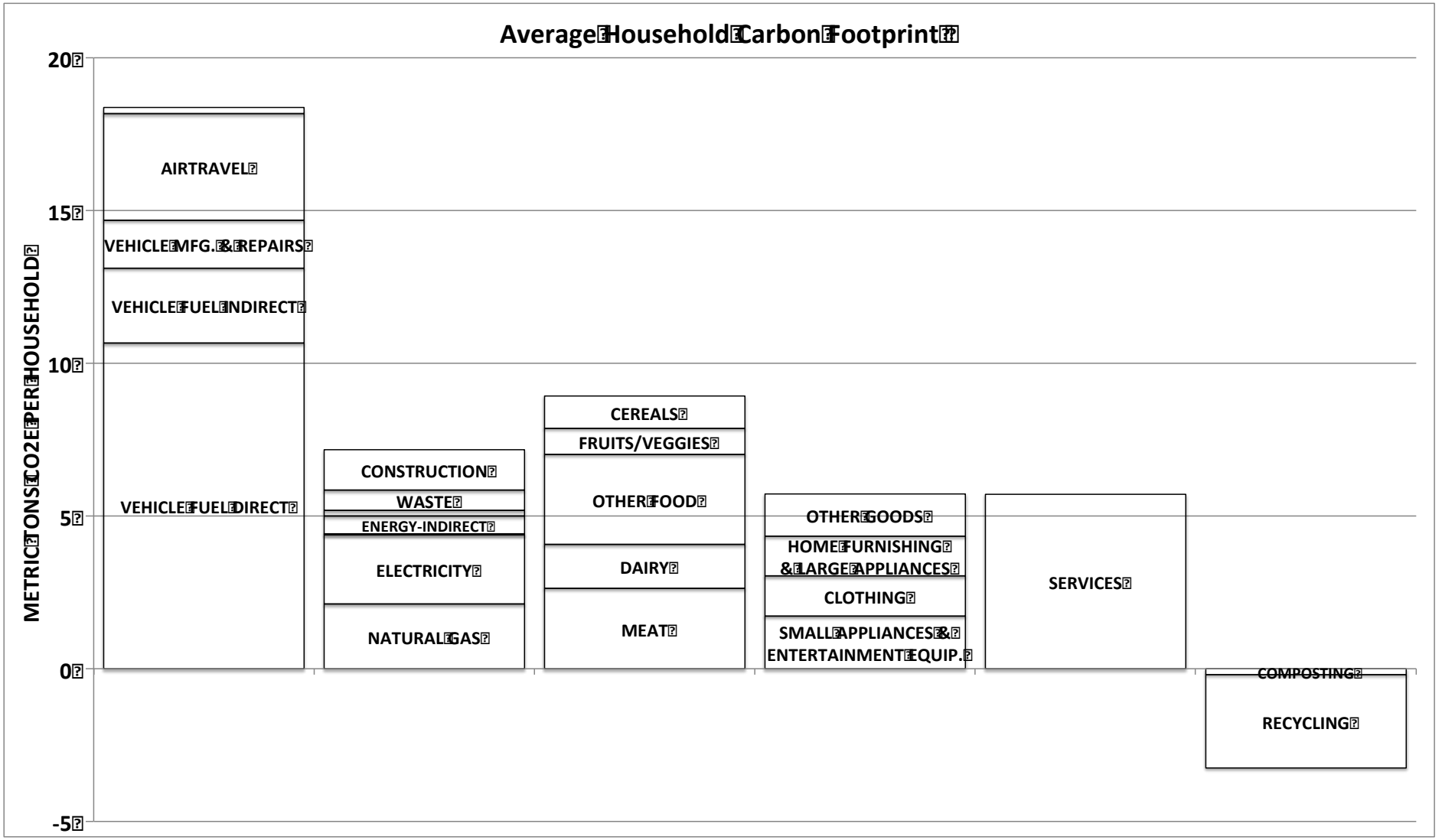

A. Electricity
LEGEND
Electricity
tCO2e / household
> 1.42 to 4
> 1.22 to 1.42
> 1.1 to 1.22
> 1.01 to 1.1
> 0.93 to 1.01
> 0.857 to 0.93
> 0.783 to 0.857
> 0.707 to 0.783
> 0.62 to 0.707
0 to 0.62
Golden Gate


B. Natural Gas
LEGEND
Natural Gas
tCO2e / household
> 7.8 to 13
> 5.66 to 7.8
> 4.45 to 5.66
> 3.6 to 4.45
> 2.9 to 3.6
> 2.32 to 2.9
> 1.8 to 2.32
> 1.25 to 1.8
> 0.7 to 1.25
0 to 0.7
Golden Gate

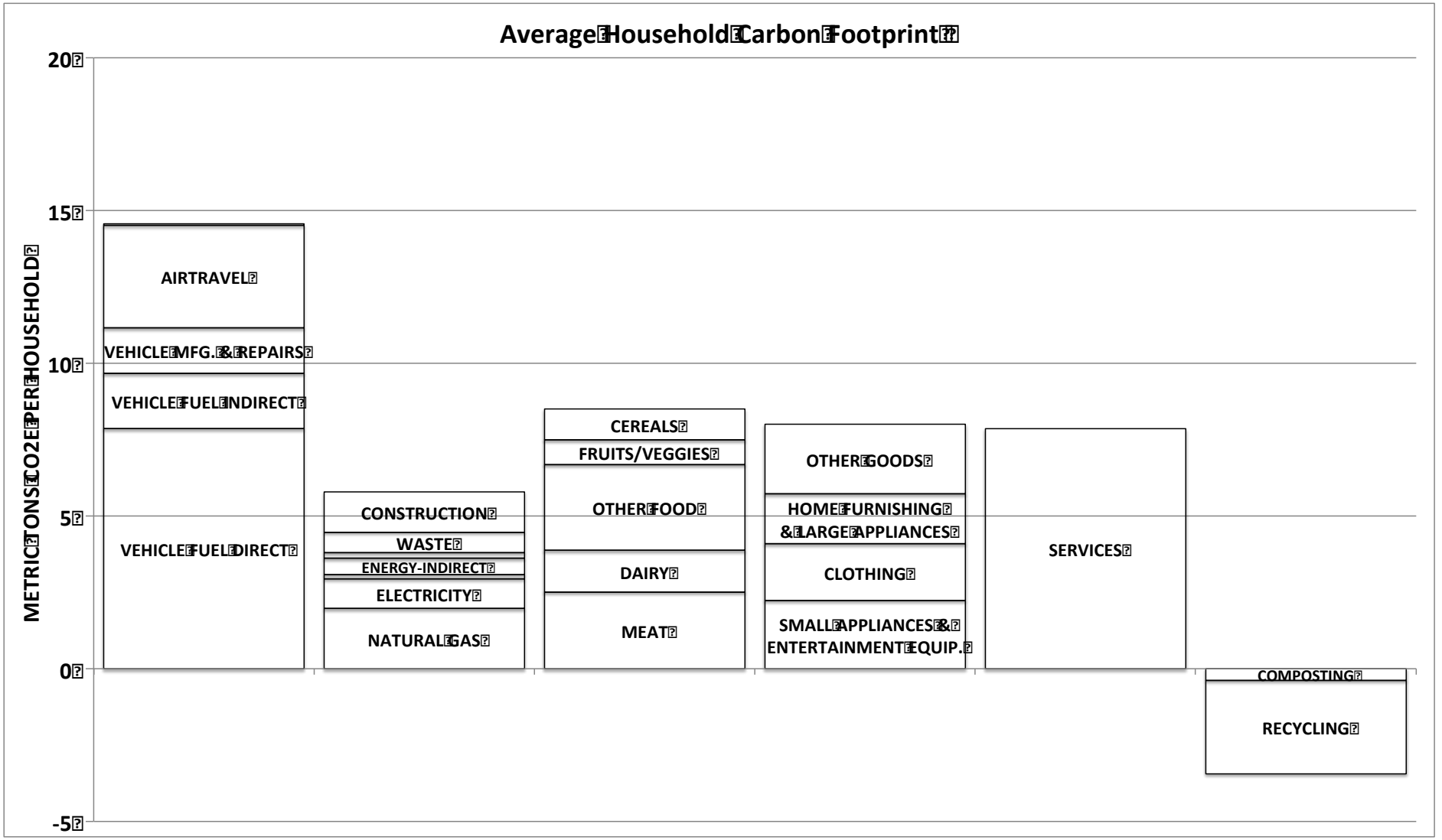
US AVERAGE	49.8 tCO2e/household	117,538,000 households	5,848,793,257 tCO2e



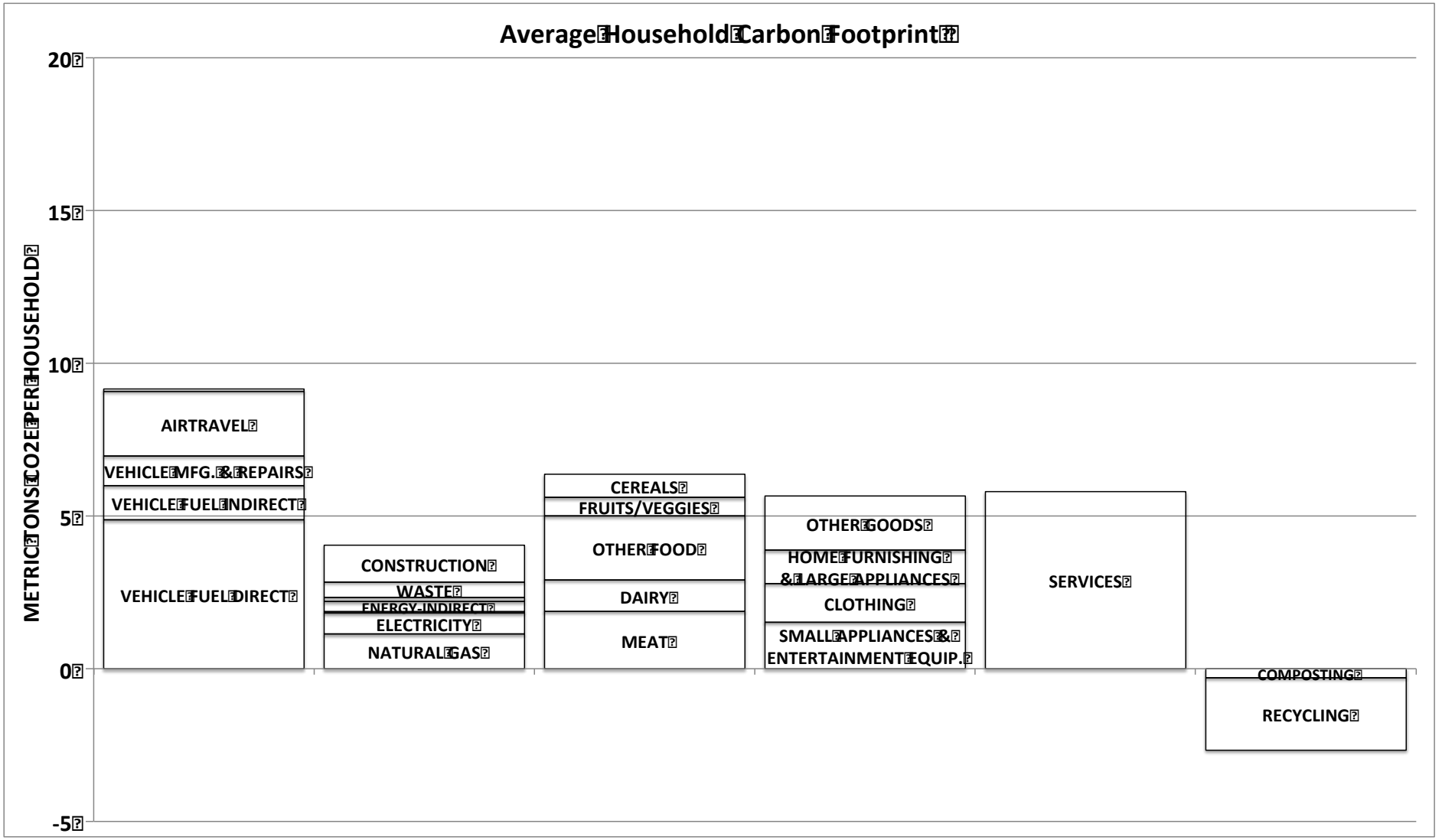
CALIFORNIA AVERAGE	15.7 tCO2e/household	12,811,083 households	85,533,297 tCO2e



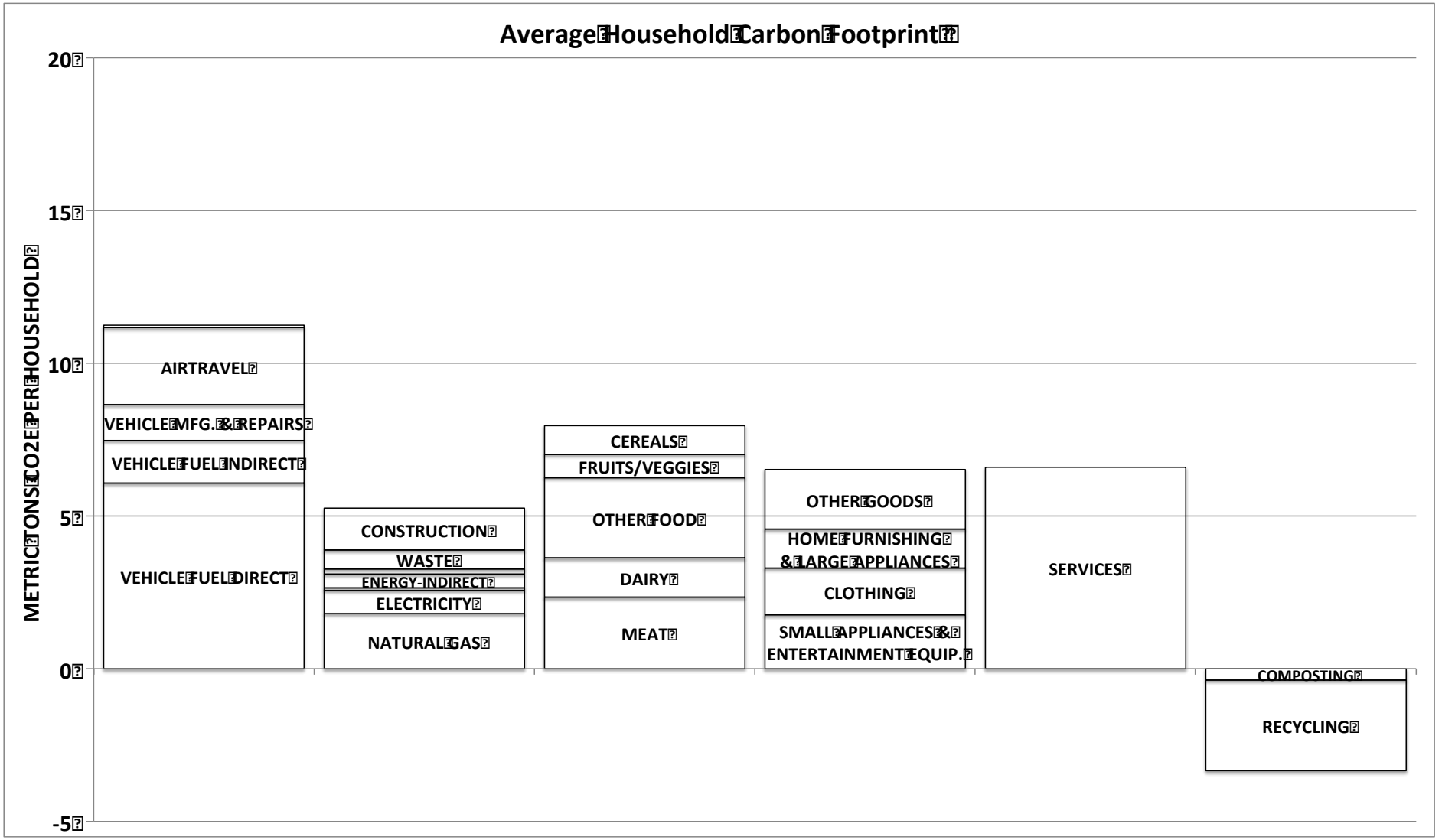
SF BAY AREA AVERAGE	14.3 tCO2e/household	2,598,944 households	15,203,994 tCO2e



CITY OF EMERYVILLE | 30.7 tCO2e/household | 15,010 households | 461,063 tCO2e

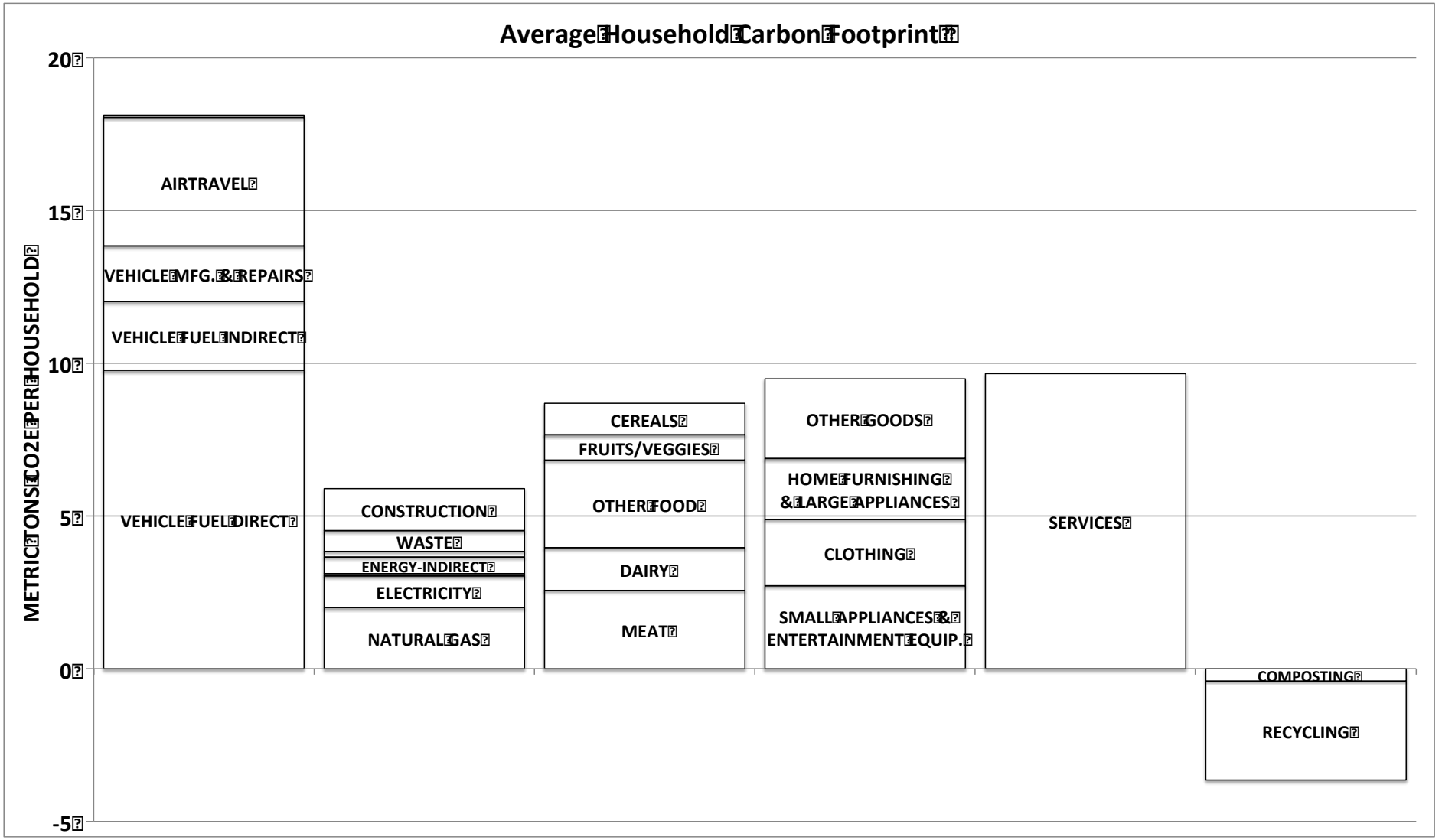


CITY OF OAKLAND | 17.2 tCO2e/household | 147,986 households | 2,504,074 tCO2e

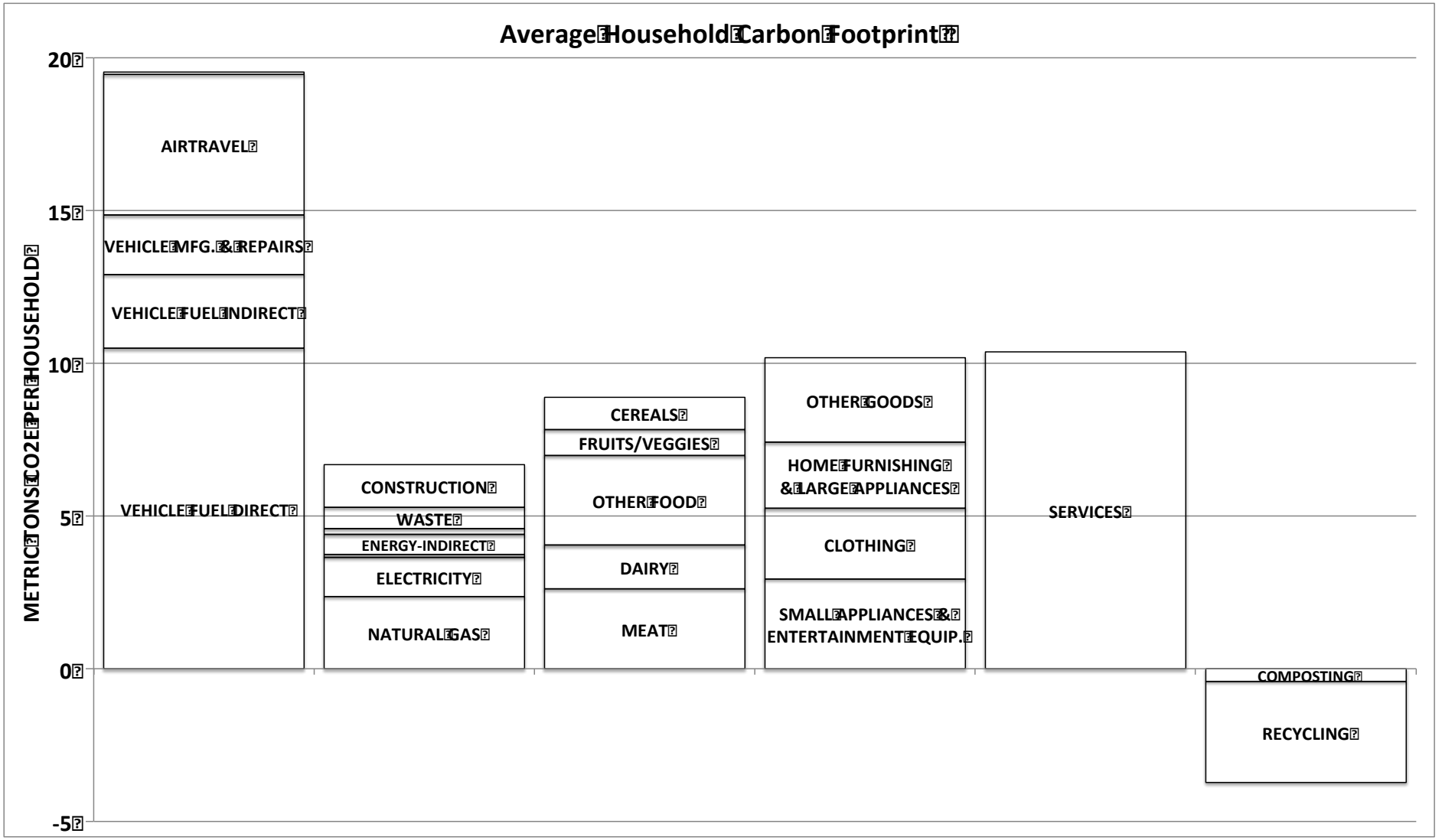


CITY OF DUBLIN

11.4 tCO2e/household **15,776** households **211,641** tCO2e



CITY OF PLEASANTON | 15.2 tCO2e/household | 25,627 households | 389,415,375 tCO2e



CBEI Methodology

- Expenditure profiles for average household in each of the ~4,700 Census block groups in Bay Area – then scale up
- Local input data:
  - Electricity & natural gas (by zip code…modified to block group)
  - Other: pubic transit, fuel economy, recycing/composting
  - Census data & weather
- Modeling using national household surveys (Bay Area respondents)
  - Consumer Expenditures Survey
  - National Household Travel Survey
  - Residential Energy Consumption Survey
- Life-cycle GHG emission factors for the "Kyoto 6" set of GHGs
  - Indirect Emissions: *Comprehensive Environmental Data Archive*
  - Bay Area-specific emissions factors (water, LCSF)

Comparison of USA and SF Bay Area models for **electricity**

Dependent variable: ln of kWh per HH

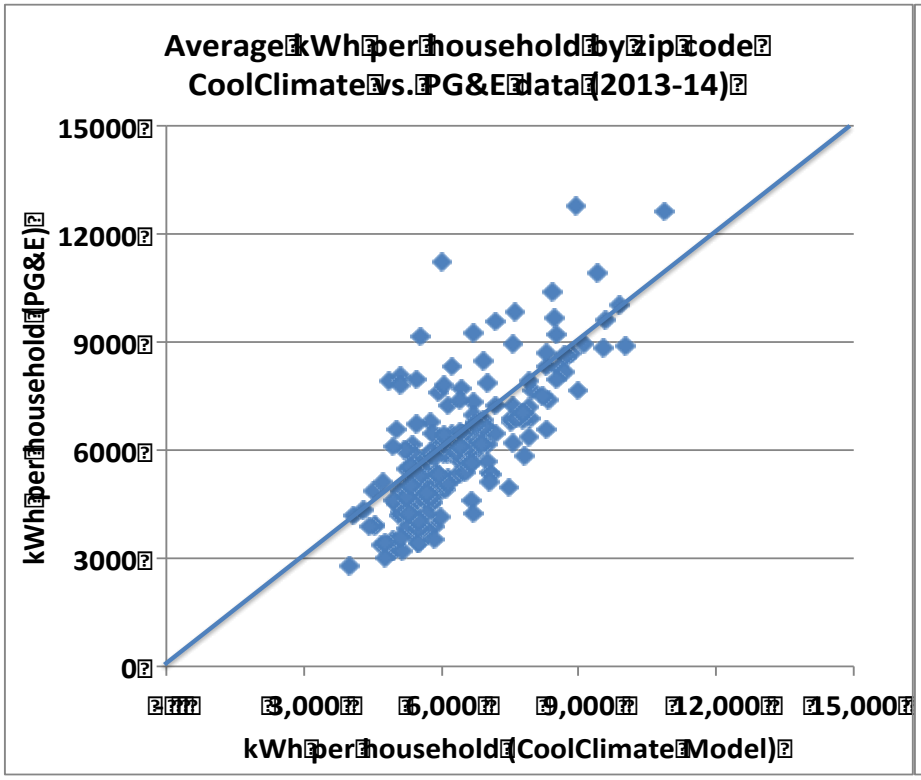
(standardized t coefficients shown in table)

<u># of Independent variables:</u>
Home Structure: 5
Economic: 3
Demographics: 7
Geographic: 7
Combined: 1
TOTAL: 23

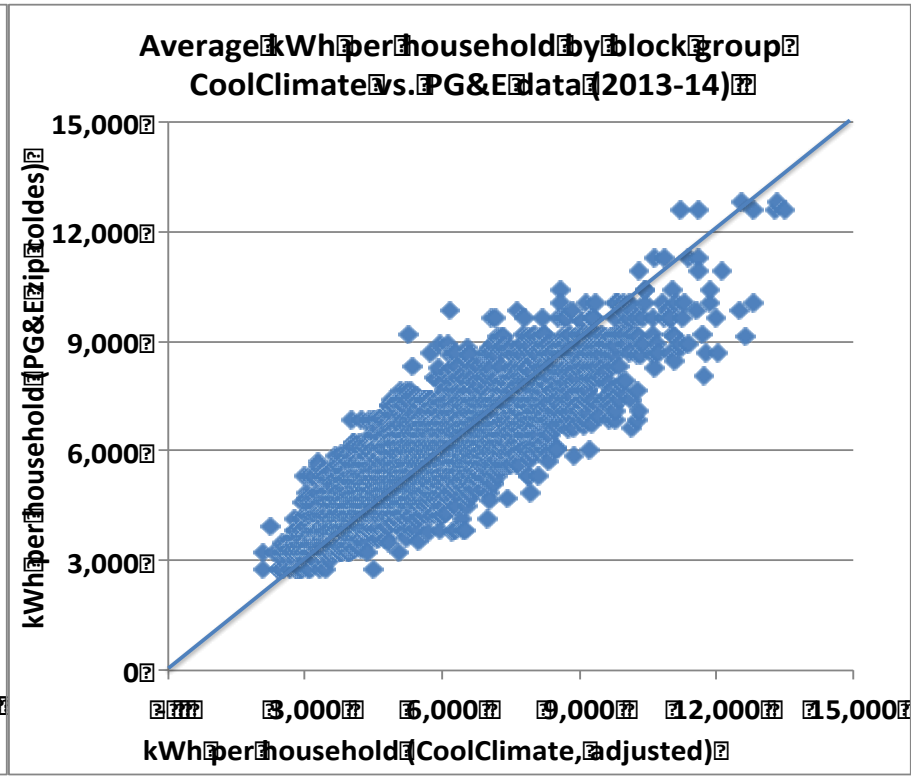
<u>Excluded:</u>
Policy
Equipment adoption rates
Behavior

Variable	Type	USA	SF Bay Area
NUMROOM	Home Structure	18.6	7.9
HTNG	Home Structure		-9.5
SQFTA	Home Structure		7.2
HTKWH	Home Structure	19.8	
DETTACHED	Home Structure	7.3	
PRICEKWH	Economic	-24.5	
PRICEKWHSQ	Economic	10.9	
OWN	Economic	3.4	5.8
LNNUMIPL1	Demographic	21.5	14.5
LNINC	Demographic	9.7	8.7
HOHASN1	Demographic		-9.8
GRAD	Demographic		-5.5
WHITE	Demographic	6	
BLACK	Demographic	4.2	
AGE	Demographic	-2.2	
CDD65	Geographic	17.5	
RURAL	Geographic	7.9	
5 Location Dummies	Geographic	-10 – 3.4	
LNCDDSQFT	Combined		11.9

Electricity model validation & adjustments

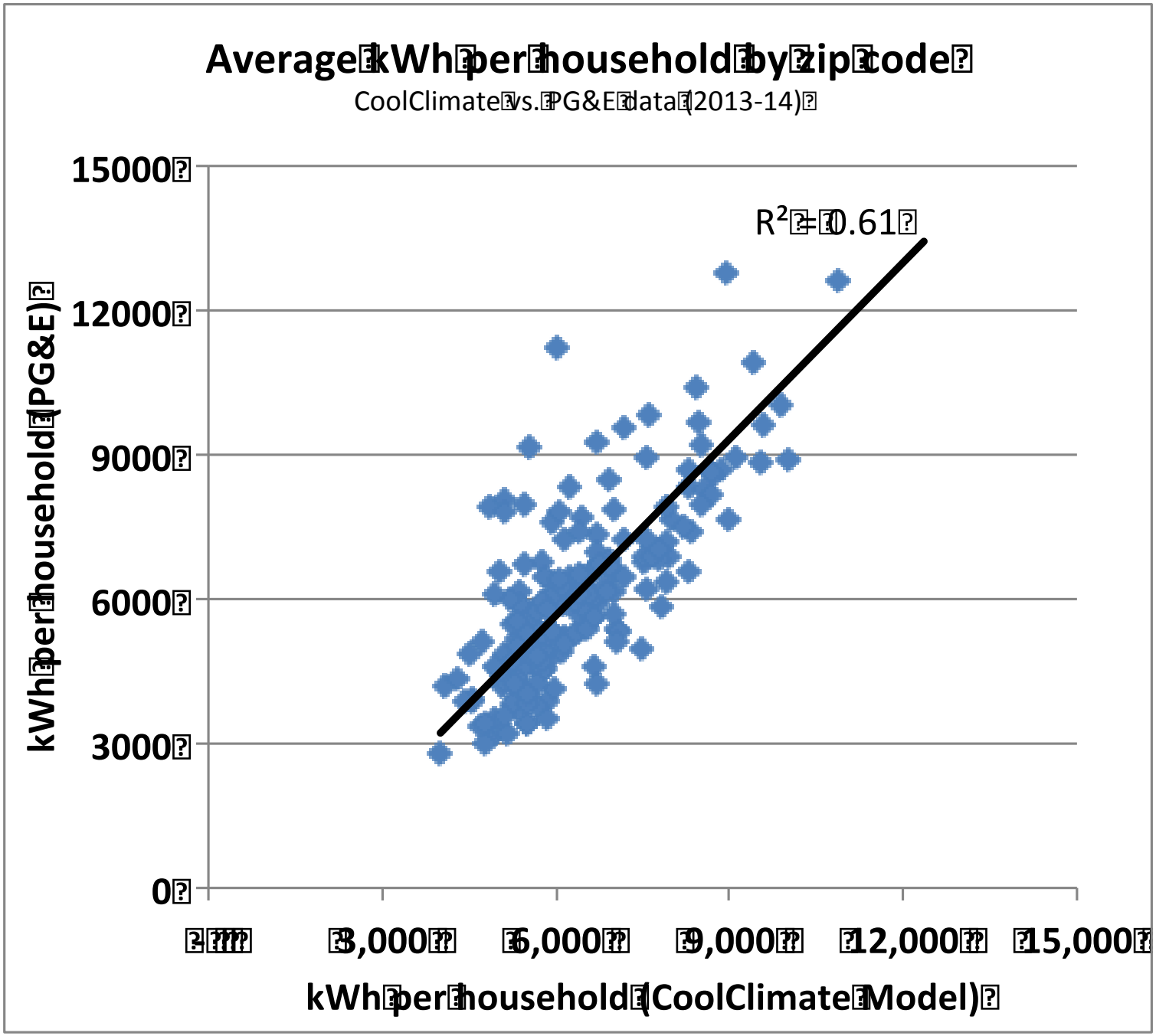


CoolClimate modeled electricity (x-axis) vs. actual electricity (y-axis) by zip code;

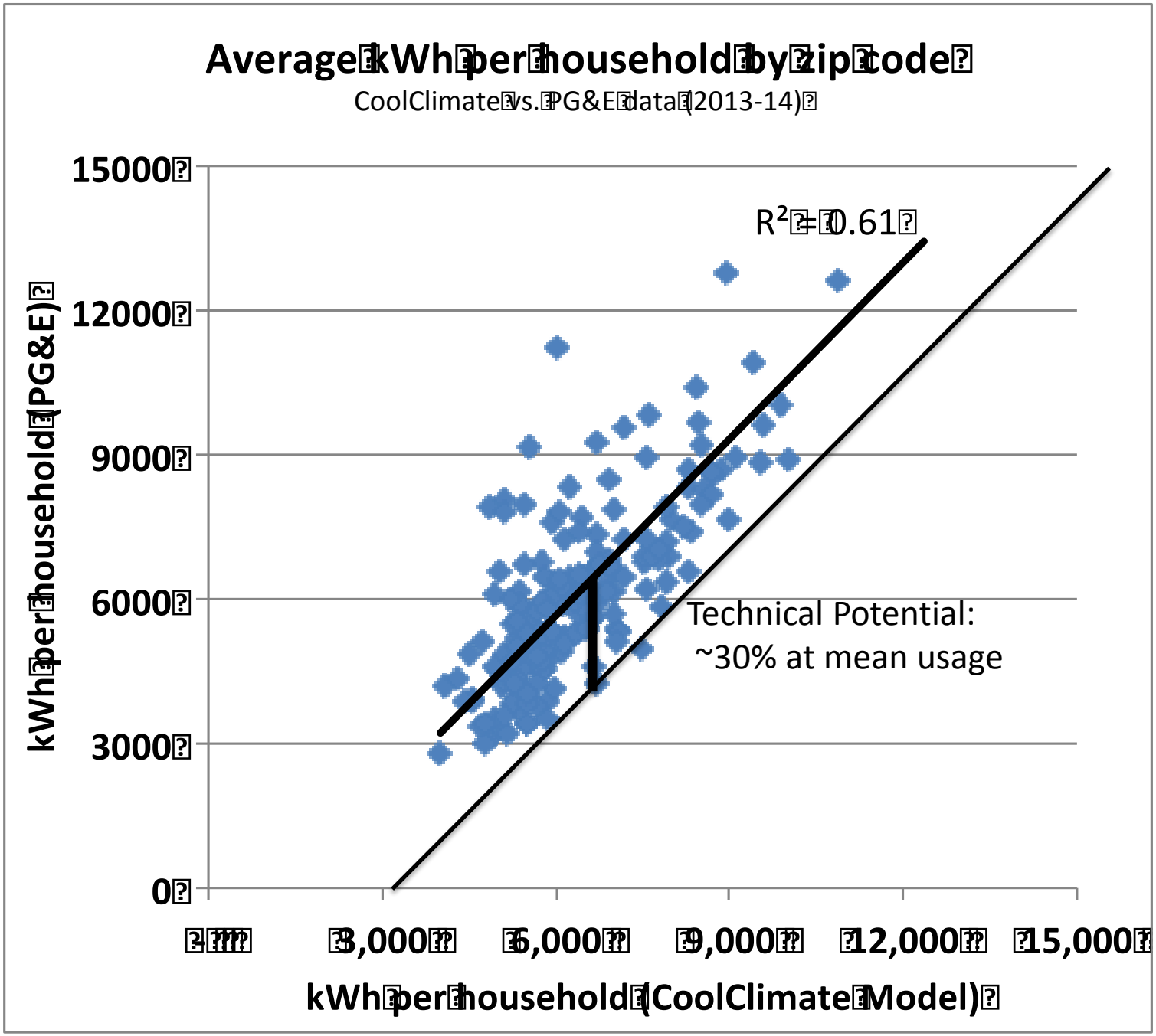


CoolClimate modeled electricity, adjusted to mean of actual by zip code (x-axis) vs. actual electricity (y-axis) by census block group

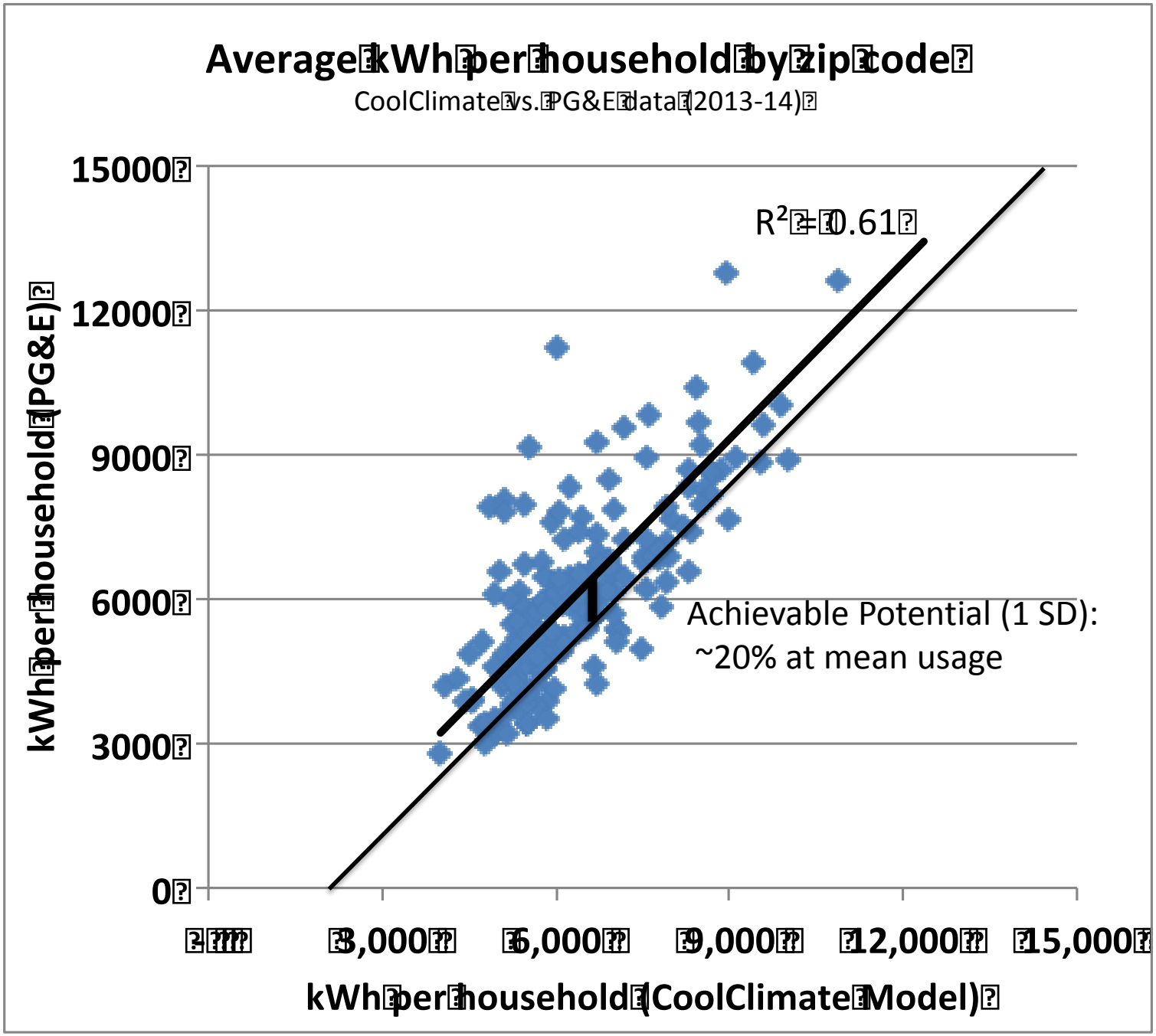
Modeled vs. Actual Result Shows Efficiency of Each Location (policy + behavior)



A Measure of Technical Potential for Energy Efficiency (electricity only)?



A Measure of Achievable Potential for Energy Efficiency (electricity only)?



Chrome File Edit View History Bookmarks Window Help

coolcalifornia.org/calculator

Intro | Travel | Housing | Food | Shopping | Take Action

Start with a quick footprint estimate

Zipcode | City | County | State

Berkeley, Alameda County, California 94704

How Many people live in your household?
Average

What is your gross annual household income?
Average

Total

27.4

tons CO_2/year

The footprint of the average household in Berkeley, California 94704 with average size and similar income.

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coolcalifornia.org/calculator

Intro | Travel | Housing | Food | Shopping | Take Action

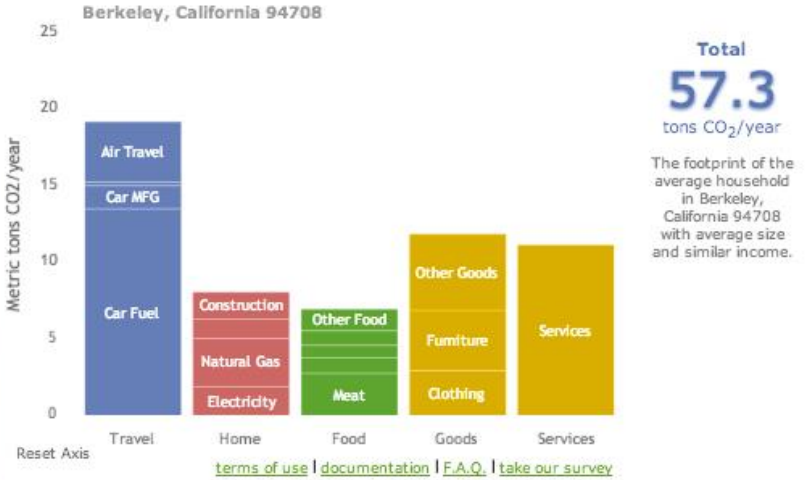
Start with a quick footprint estimate

Zipcode | City | County | State

Berkeley, Alameda County, California 94708

How Many people live in your household?
Average

What is your gross annual household income?
Average



Total

57.3

tons CO_2/year

The footprint of the average household in Berkeley, California 94708 with average size and similar income.

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coolcalifornia.org/calculator

Intro | Travel | Housing | Food | Shopping | Take Action

How do you get around?

Vehicle 1 Miles per year: 14600 Miles per gallon: 22 Gasoline

\+ -

Public Transit

Simple | Advanced

1003 miles per year

Air Travel

Simple | Advanced

200 miles flown per year

Berkeley, California 94708

Total Travel

9.2

tons CO_2/year

52.1% Better than the average household in Berkeley, California 94708 with average size and similar income.

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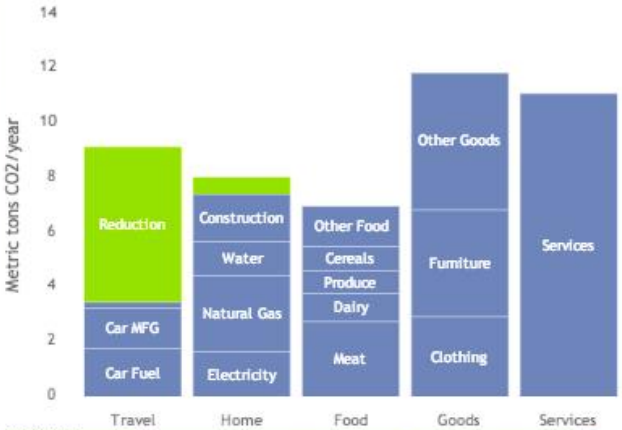
Intro | Travel | Housing | Food | Shopping | Take Action

Build your action plan



Reset Axis

Total Reductions

6.5

tons CO_2/year

$/yr saved: $2834

Upfront cost: $17890

Total Footprint

40.8

tons CO_2/year

28.8% Better than the average household in Berkeley, California 94708 with average size and similar income.

Assumptions | Transportation | Housing | Shopping | Offset

Save to my profile

	Category	Tons Saved $mtCO_2e/yr$	Dollars Saved $/yr	Upfront Cost $/yr
Pledge	Buy a More Efficient Vehicle	2.32	$726	$2000
Pledge	Buy an Alternative Fuel Vehicle	2.45	$797	$17000
Pledge	Buy an Electric Vehicle	7.39	$1866	$15000
Pledge	Buy a Hybrid Vehicle	3.34	$1045	$15000
Pledge	Telecommute to Work	0.98	$545	$0
Pledge	Ride my Bike	0.53	$165	$0

I will ride my bike 20 miles per week instead of driving Vehicle 1 which gets 22 miles per gallon.

Your bicycle can make you a lean, green clean-moving machine! Free tools like google maps have bike-friendly directions to get you going as an exemplary neighborhood cyclist.

[+] assumptions

Pledge	Take Public Transportation	0.42	$165	$0

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Typical California School

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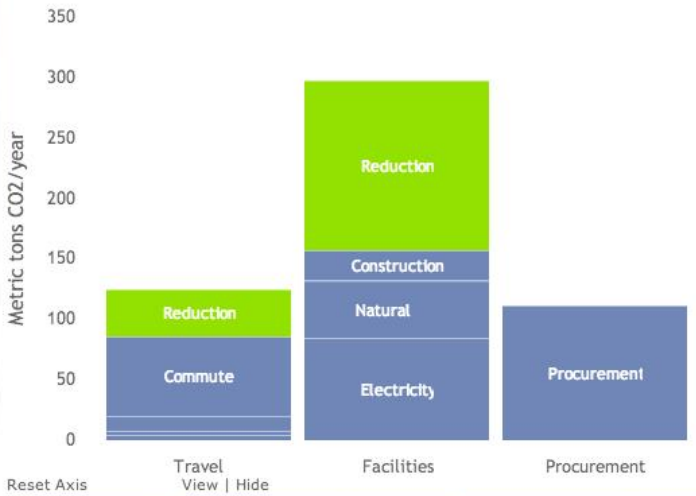
Small Business Carbon Footprint Calculator

Intro | Travel | Facilities | Procurement | Summary | Take Action

Build your action plan



Reset Axis | View | Hide

Total Reductions
189.7
tons CO_2/year
$/yr saved: $16516
Upfront cost: $170921

Total Footprint
344.4
tons CO_2/year

35.5% Better
than similar businesses

Assumptions | Transportation | Facilities | Procurement | Offset | CA Green Biz Prog

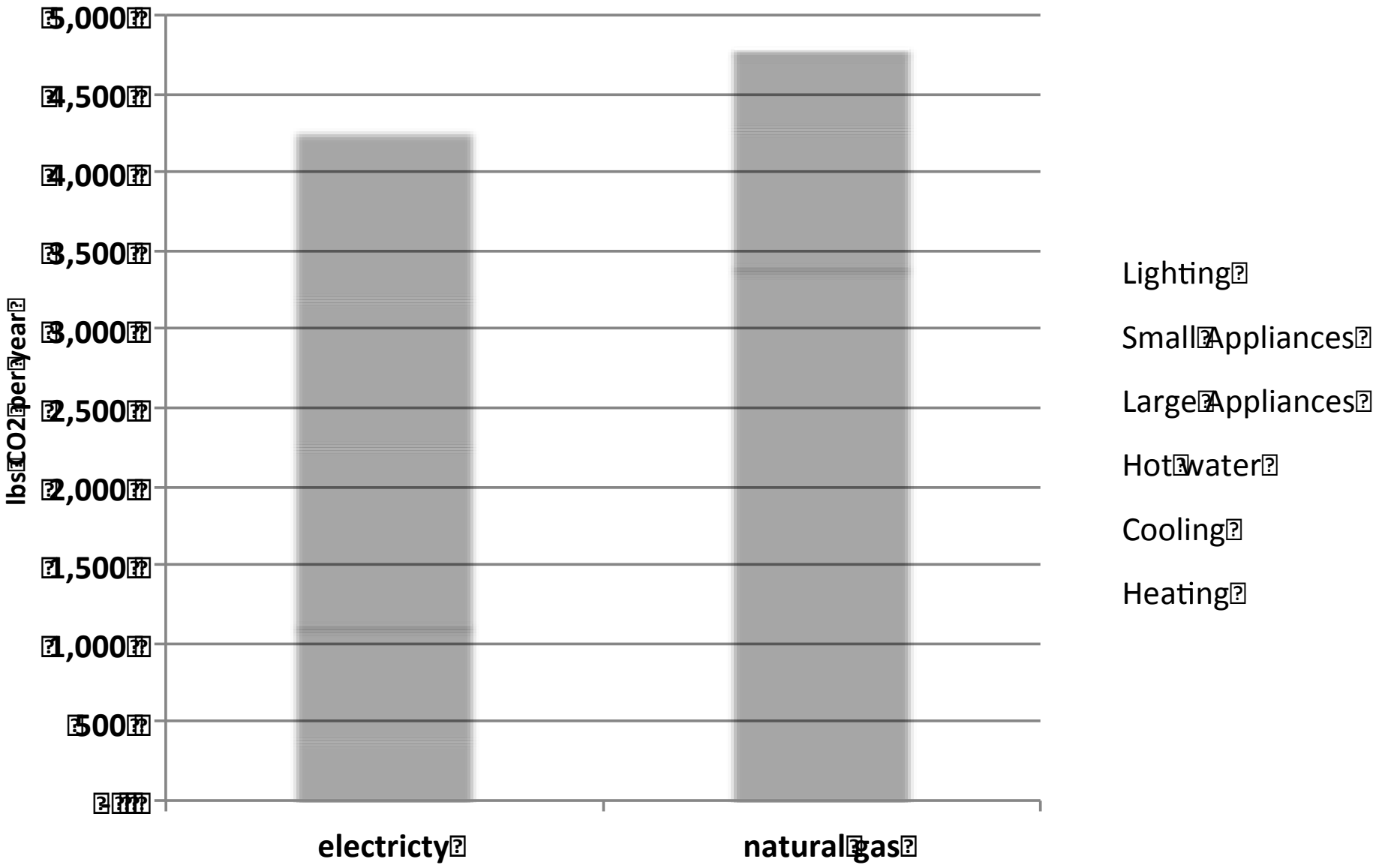
Print (or save as PDF)

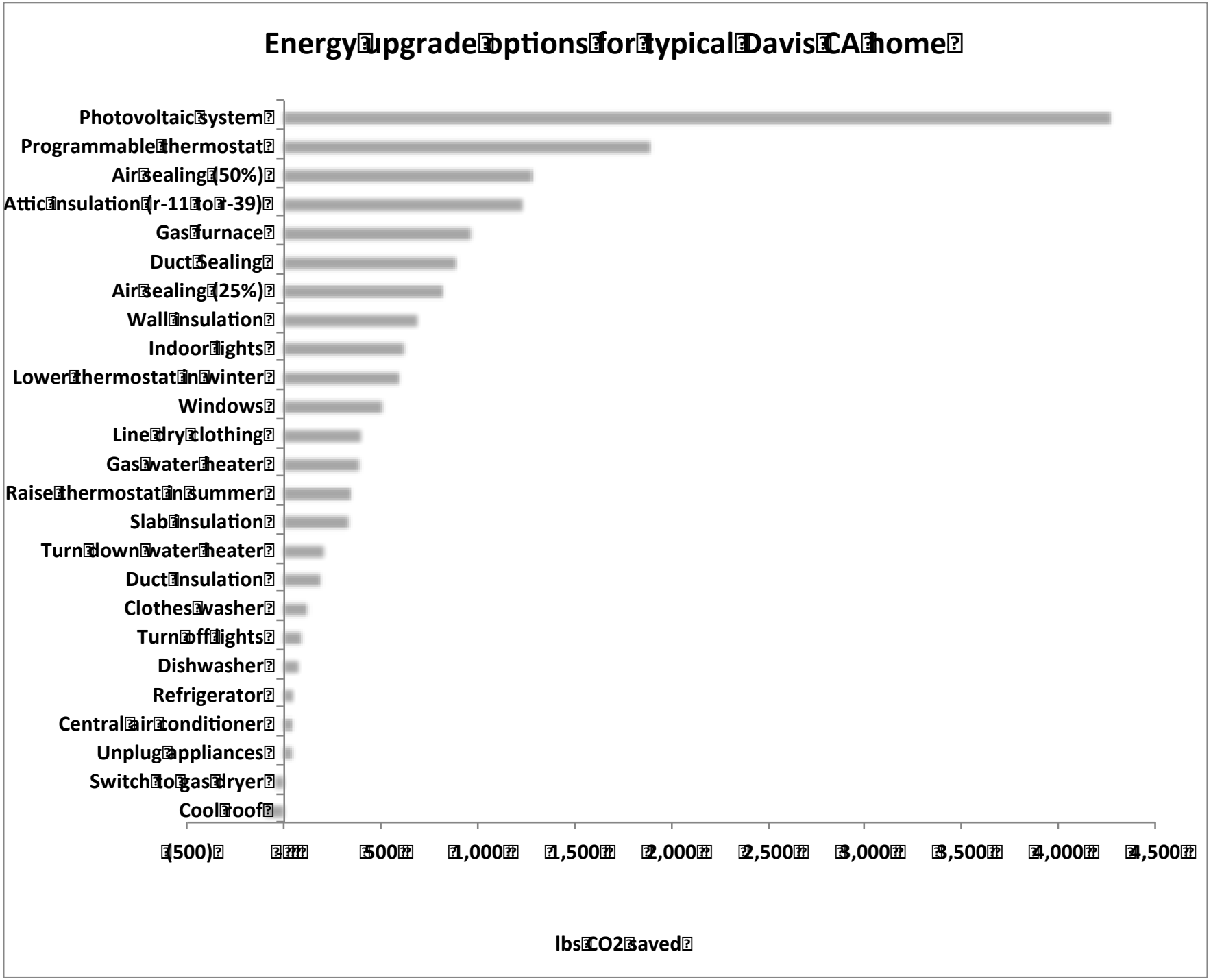
Sort By: Category | Tons Saved $mtCO_2e/yr$ ↑ | Dollars Saved $/yr | Upfront Cost $/yr

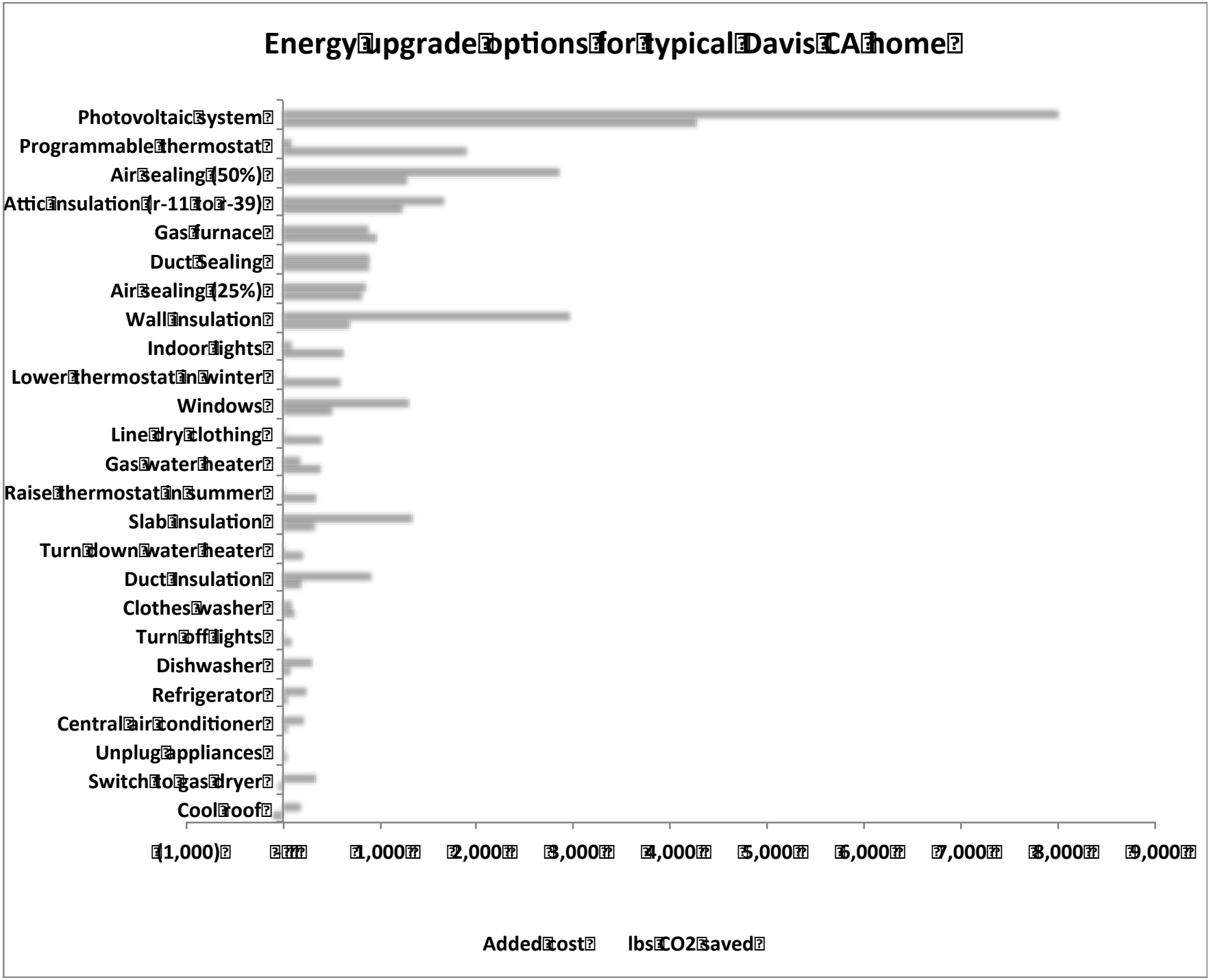
		Tons Saved	Dollars Saved	Upfront Cost
Pledge	Offset Remaining Facilities	157.13	$0	$3143
Pledge	Purchase Green Electricity	192.78	$0	$3852
Pledge	Offset Remaining Transportation	76.22	$0	$1524
Pledge	Install PV Panels	96.29	$15505	$165350
Pledge	Telecommute to Work	48.78	$0	$2400
Pledge	Install LED Outdoor Parking Lights with Motion Sensors	44.58	$1011	$3170

Energy carbon footprint from typical Davis CA homes

source: CoolCalifornia.org/calculator




Energy upgrade options for typical Davis CA home
Photovoltaic system
Programmable thermostat
Air sealing (50%)
Attic insulation (r-11 to r-39)
Gas furnace
Duct Sealing
Air sealing (25%)
Wall insulation
Indoor lights
Lower thermostat in winter
Windows
Line dry clothing
Gas water heater
Raise thermostat in summer
Slab insulation
Turn down water heater
Duct insulation
Clothes washer
Turn off lights
Dishwasher
Refrigerator
Central air conditioner
Unplug appliances
Switch to gas dryer
Cool roof
(500)
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
lbs CO2 saved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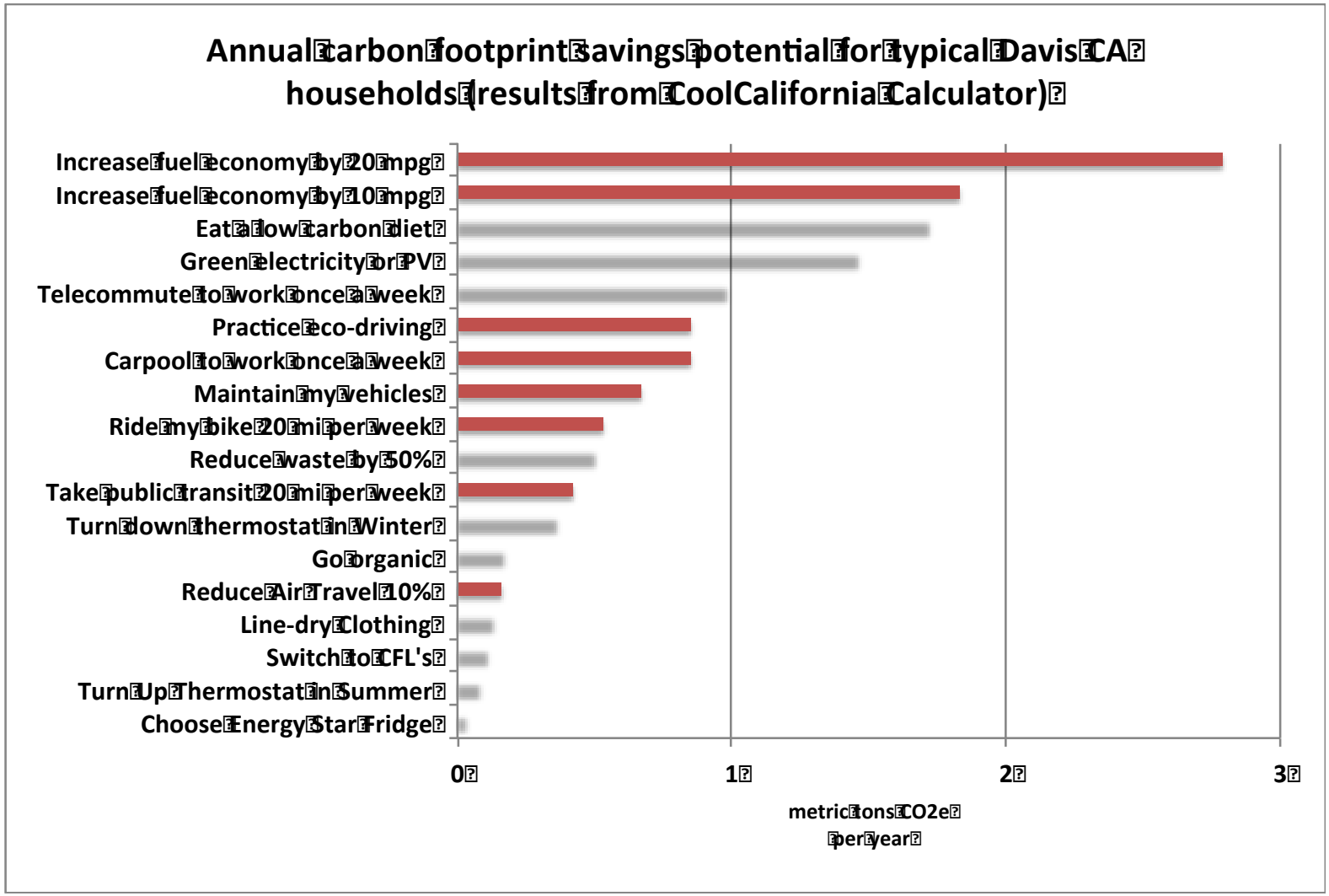
Turn off lights
Dishwasher
Refrigerator
Central air conditioner
Unplug appliances
Switch to gas dryer
Cool roof
(1,000)
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Added cost
lbs CO2 saved


Annual carbon footprint savings potential for typical Davis CA households (results from CoolCalifornia Calculator)
Increase fuel economy by 20 mpg
Increase fuel economy by 10 mpg
Eat a low carbon diet
Green electricity or PV
Telecommute to work once a week
Practice eco-driving
Carpool to work once a week
Maintain my vehicles
Ride my bike 20 mi per week
Reduce waste by 50%
Take public transit 20 mi per week
Turn down thermostat in Winter
Go organic
Reduce Air Travel 10%
Line-dry Clothing
Switch to CFL's
Turn Up Thermostat in Summer
Choose Energy Star Fridge
0
1
2
3
metric tons CO2e per year

Mitigation Wedges
California Max Scenario

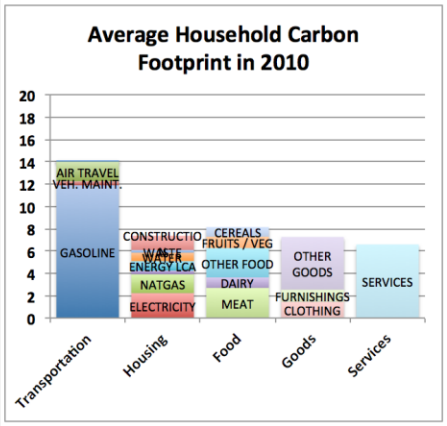
	2010	2020	2030	2040	2050
Transportation	176,214,168	136,680,214	98,887,208	64,093,360	33,342,082
Housing	26,384,619	37,574,080	39,286,176	32,734,032	19,132,003
Food	102,186,301	101,484,957	99,552,530	96,416,021	91,951,729
Goods	91,036,028	83,711,302	74,866,186	64,681,621	53,338,547
Services	82,686,583	80,208,374	75,702,073	69,059,209	60,171,313
Electric Vehicles	-	7,893,971	33,099,101	46,241,177	57,442,113
50+ MPG Vehicles	-	8,067,348	4,427,473	4,669,645	4,210,177
Urban Infill	-	726,354	2,031,162	3,034,071	3,381,005
VMT Reduction	-	6,693,794	11,969,961	15,920,690	17,456,730
Low Carbon Vehicle Fuels	-	6,699,094	12,113,469	16,507,803	20,048,462
Air Travel Efficiency	-	9,534,452	19,923,513	31,011,271	42,641,813
Air Travel Reduction	-	6,370,312	13,566,762	21,348,724	29,446,902
Renewable Electricity	-	2,323,566	4,600,514	6,734,749	8,630,174
Energy Efficiency	-	2,995,373	5,217,057	5,921,775	4,619,629
Energy Conservation	-	2,983,725	4,176,271	3,727,848	2,150,638
Heating Electrification	-	1,725,663	3,108,913	3,515,727	2,896,313
Home Size Efficiency	-	363,177	1,015,581	1,517,035	1,690,502
Waste Efficiency & Cons.	-	505,778	986,199	1,419,700	1,784,721
Water Conservation	-	1,210,522	2,229,000	3,012,024	3,516,189
Commercial Efficiency	-	4,473,352	9,624,750	15,454,194	21,961,684
Industrial Efficieny	-	4,925,058	10,596,629	17,014,713	24,179,310
Shift Consumption	-	2,163,878	3,990,638	5,339,713	6,070,538
Agricultural Efficiency	-	6,910,361	14,868,156	23,873,386	33,926,049
Health Diets	-	2,283,928	4,515,606	6,610,826	8,485,381
Taxation	-	-	-	-	-
TOTAL BEFORE MITIGATION	528,507,698	543,508,634	550,354,929	549,859,314	542,474,008
MITIGATION	-	83,849,706	162,060,756	232,875,072	294,538,333
TOTAL AFTER MITIGATION	528,507,698	459,658,928	388,294,174	316,984,242	247,935,676

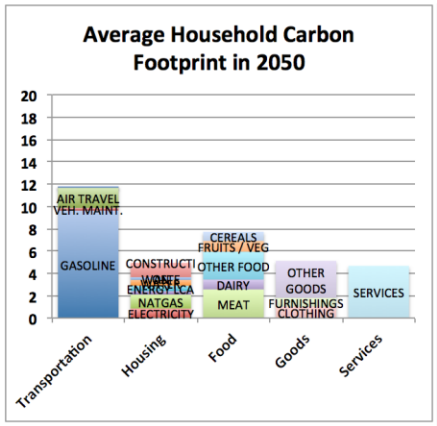
SELECT

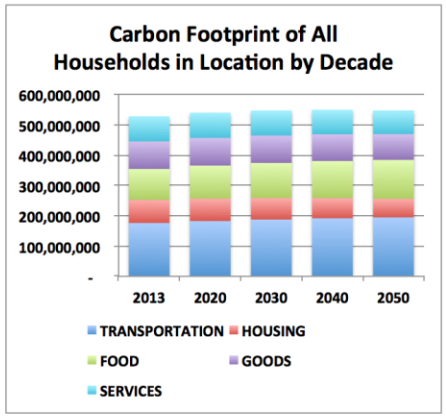
STATE

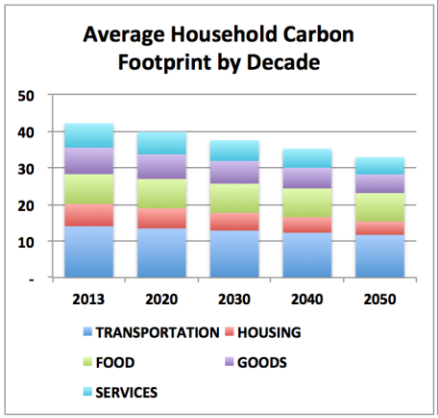
Scenario 1) BAU

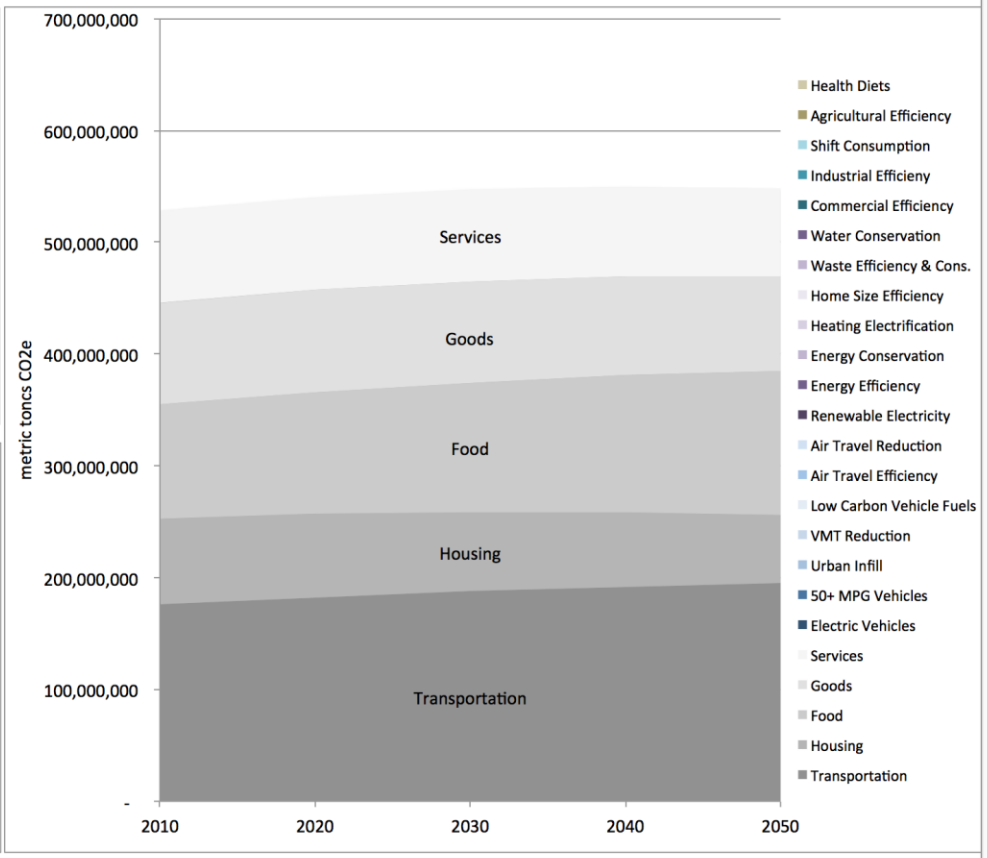
Consumption-based GHG inventory 2010:	528,507,698	tCO2	
Consumption-based GHG inventory 2050:	547,784,109	tCO2	-3.6% reduction
Average household carbon footprint 2010:	42.12	tCO2	
Average household carbon footprint 2050:	32.86	tCO2	22.0% reduction











DASHBOARD | Population | Bayarea | CARBON FOOTPRINT | CONSUMPTION | BGDATA | GHG FACTORS | Notes | figures | GOODSSERVICES | FO MODEL | NC

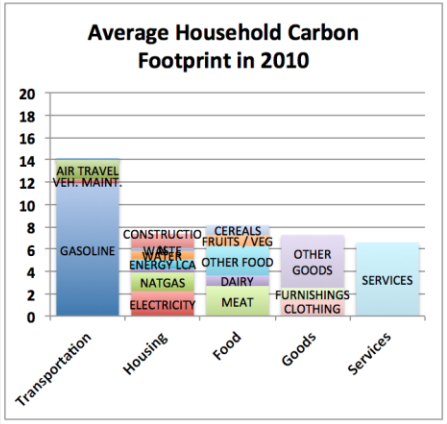
Normal View | Ready | Sum=0

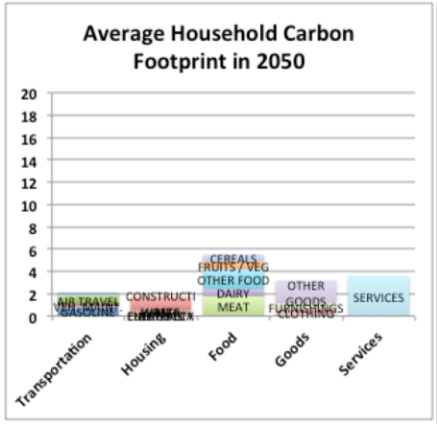
SELECT

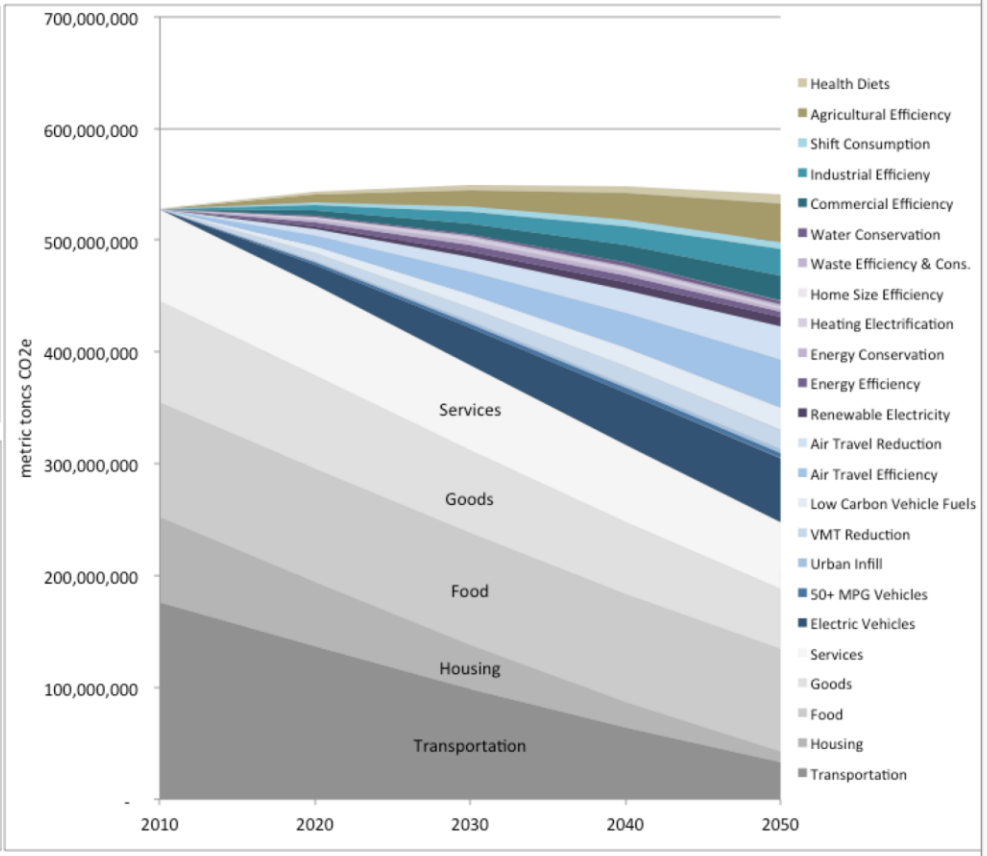
STATE

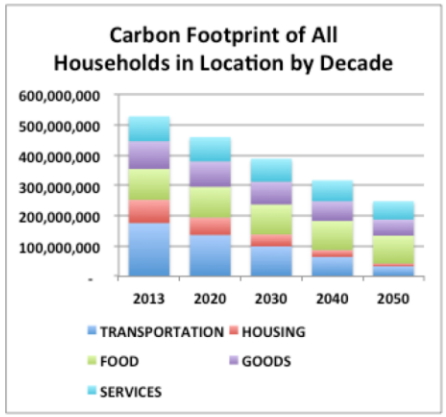
Scenario 6) Max

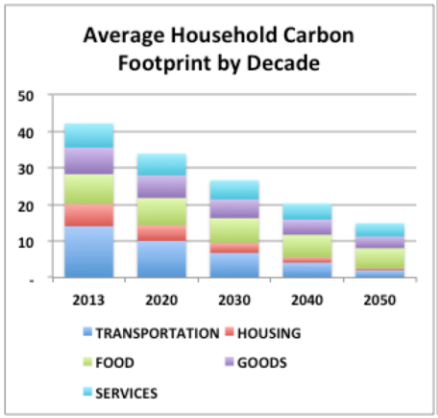
Consumption-based GHG inventory 2010:	528,507,698	tCO2	
Consumption-based GHG inventory 2050:	247,935,676	tCO2	53.1% reduction
Average household carbon footprint 2010:	42.12	tCO2	
Average household carbon footprint 2050:	14.85	tCO2	64.7% reduction











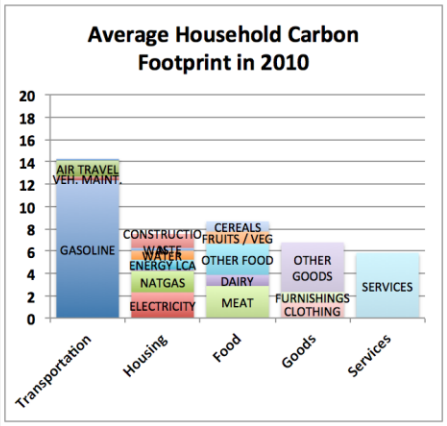
DASHBOARD | Population | Bayarea | CARBON FOOTPRINT | CONSUMPTION | BGDATA | GHG FACTORS | Notes | figures | GOODSSERVICES | FO MODEL | NC

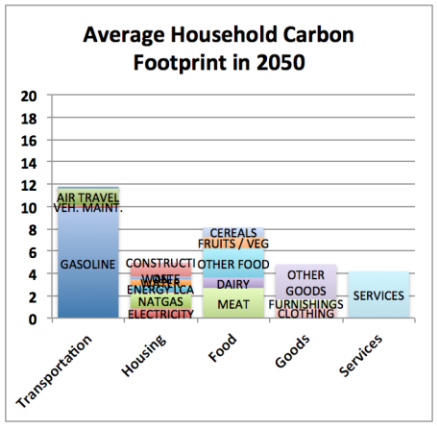
Normal View | Ready | Sum=0

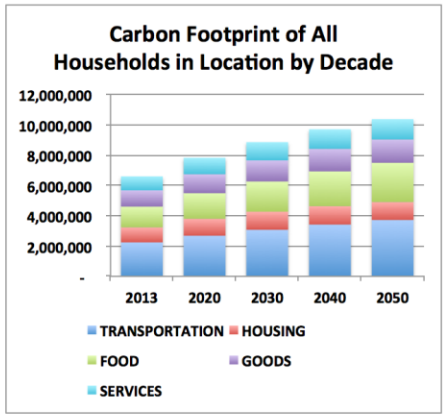
SELECT

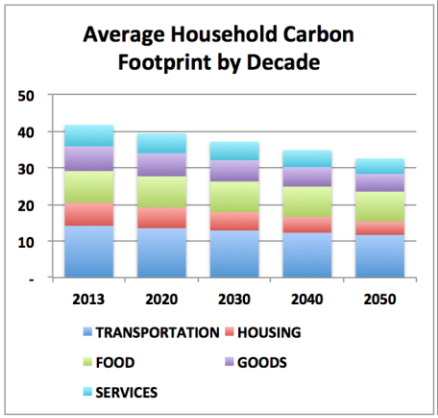
CITY
BAKERSFIELD
Scenario 1) BAU

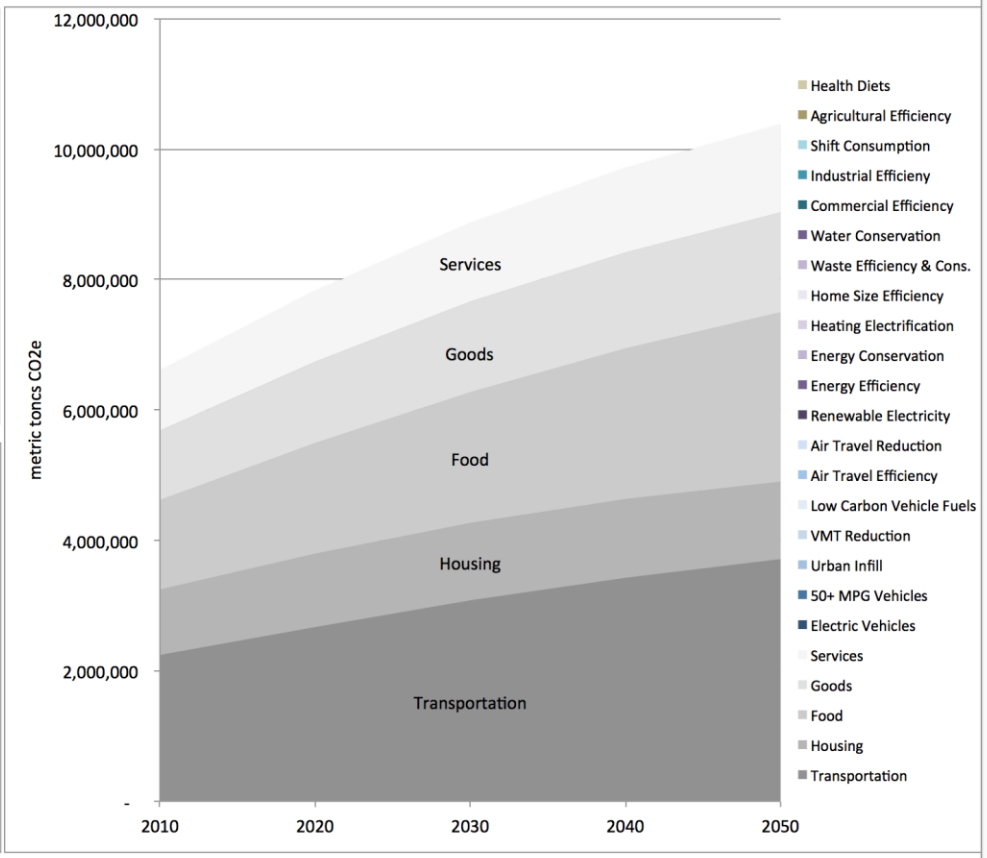
Consumption-based GHG inventory 2010:	6,603,105	tCO2	
Consumption-based GHG inventory 2050:	10,380,037	tCO2	-57.2% reduction
Average household carbon footprint 2010:	41.71	tCO2	
Average household carbon footprint 2050:	32.52	tCO2	22.0% reduction











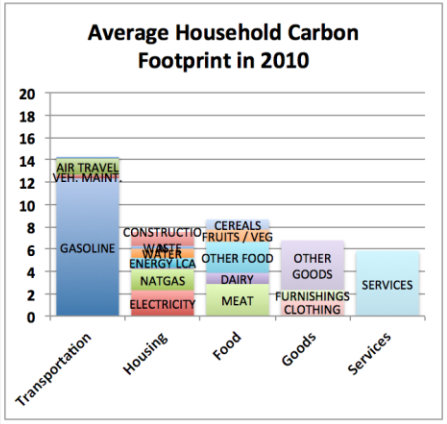
DASHBOARD | Population | Bayarea | CARBON FOOTPRINT | CONSUMPTION | BGDATA | GHG FACTORS | Notes | figures | GOODSSERVICES | FO MODEL | NC

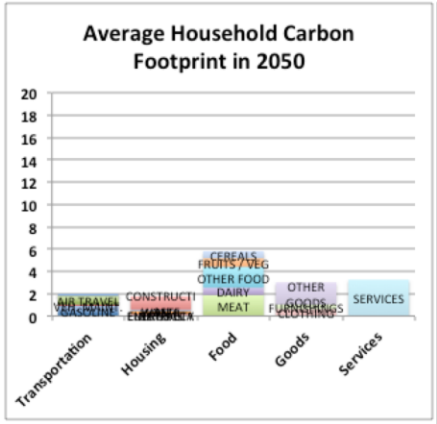
Normal View | Ready | Sum=0

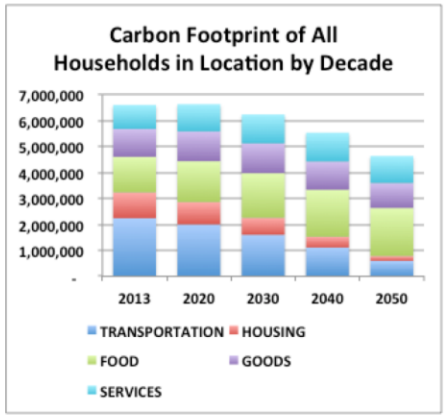
SELECT

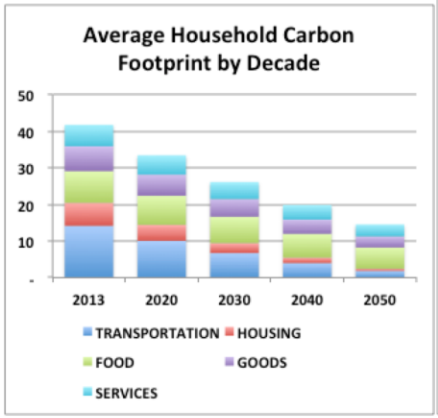
CITY
BAKERSFIELD
Scenario 6) Max

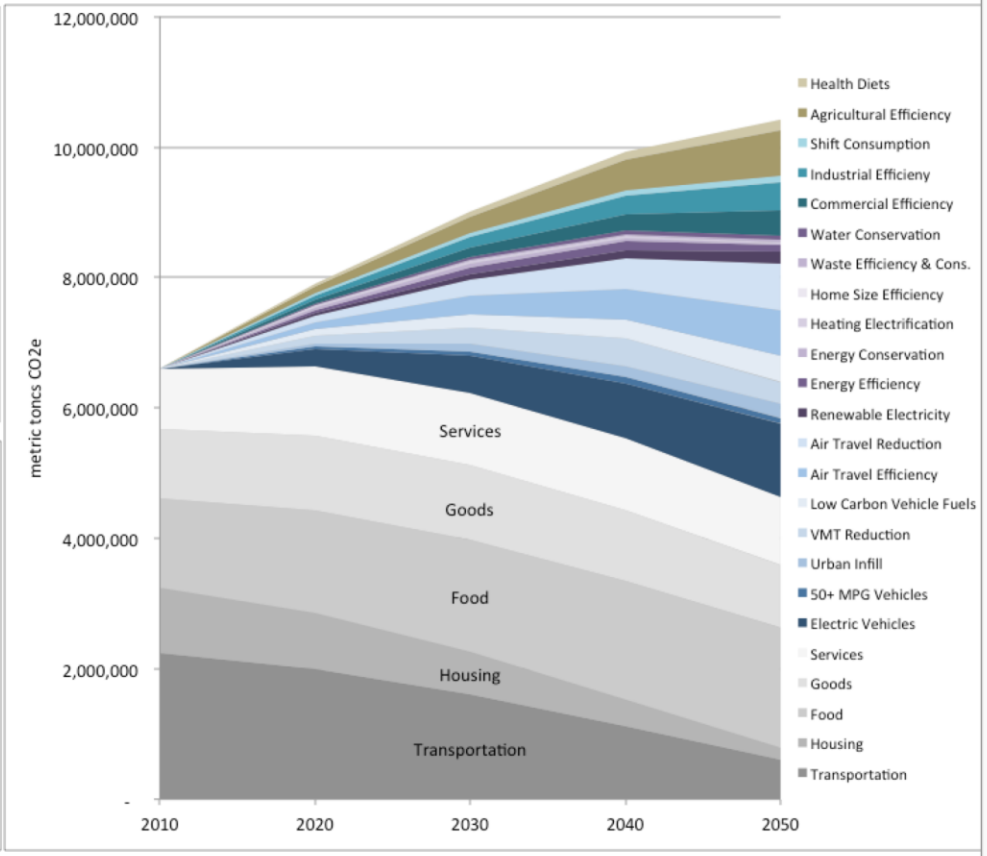
Consumption-based GHG inventory 2010:	6,603,105	tCO2	
Consumption-based GHG inventory 2050:	4,635,114	tCO2	29.8% reduction
Average household carbon footprint 2010:	41.71	tCO2	
Average household carbon footprint 2050:	14.50	tCO2	65.2% reduction











DASHBOARD | Population | Bayarea | CARBON FOOTPRINT | CONSUMPTION | BGDATA | GHG FACTORS | Notes | figures | GOODSSERVICES | FO MODEL | NC

Normal View | Ready | Sum=0

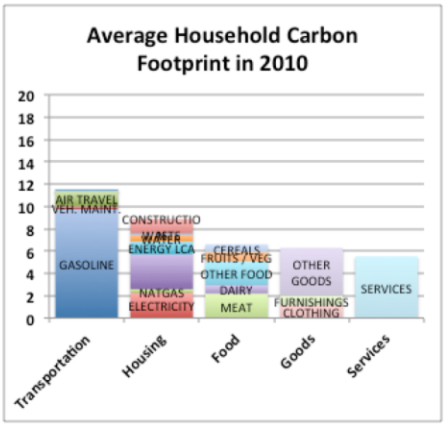
SELECT

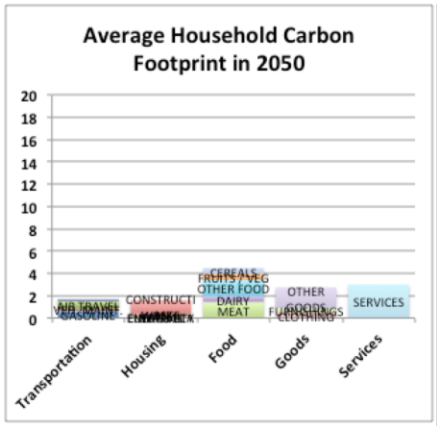
CITY

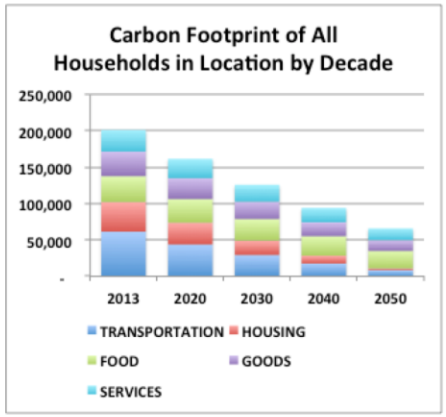
BISHOP

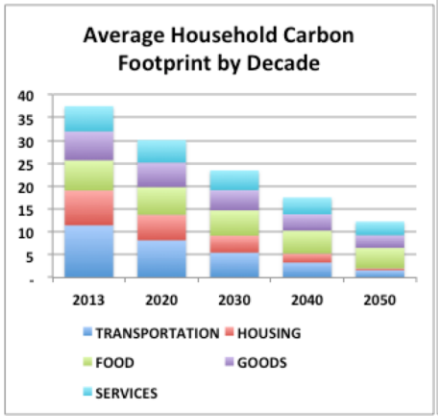
Scenario 6) Max

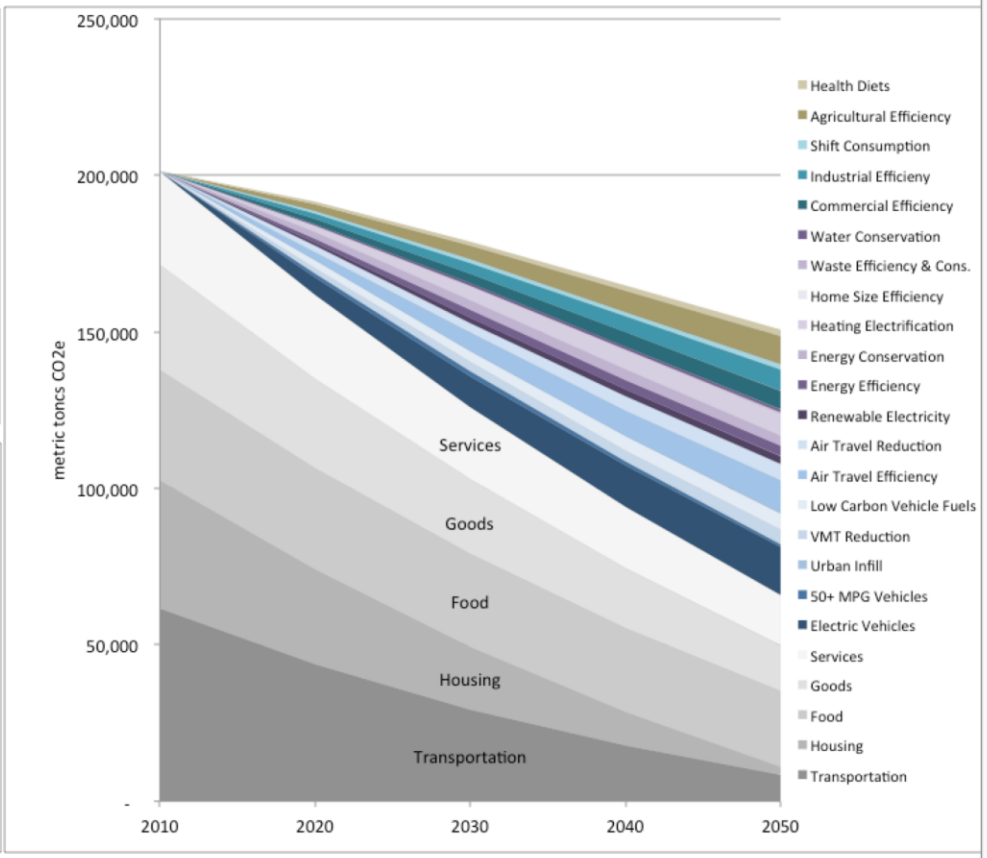
Consumption-based GHG inventory 2010:	201,396	tCO2	
Consumption-based GHG inventory 2050:	65,919	tCO2	67.3% reduction
Average household carbon footprint 2010:	37.44	tCO2	
Average household carbon footprint 2050:	12.23	tCO2	67.3% reduction











DASHBOARD | Population | Bayarea | CARBON FOOTPRINT | CONSUMPTION | BGDATA | GHG FACTORS | Notes | figures | GOODSSERVICES | FO MODEL | NC

Normal View | Ready | Sum=0

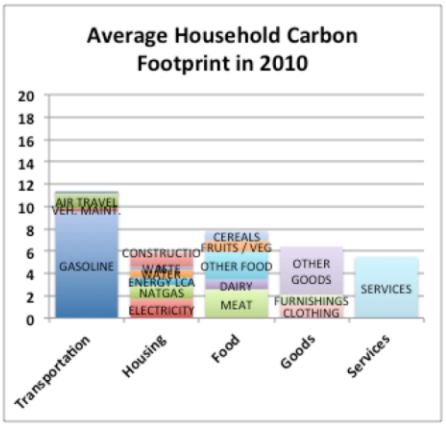
SELECT

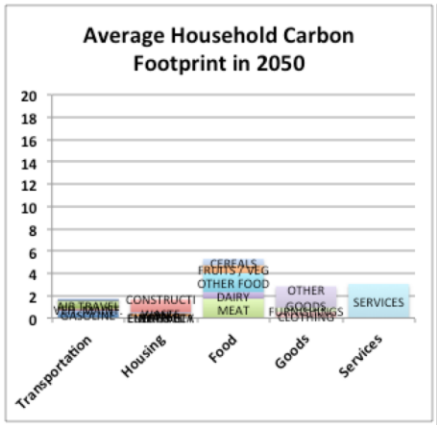
CITY

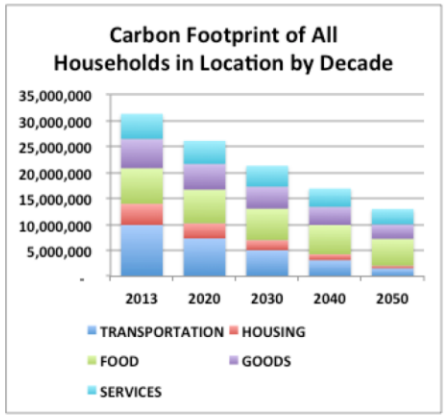
LOS ANGELES

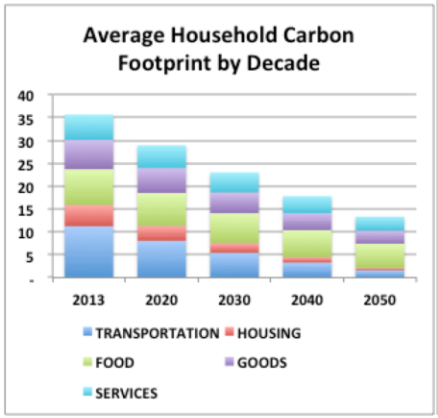
Scenario 6) Max

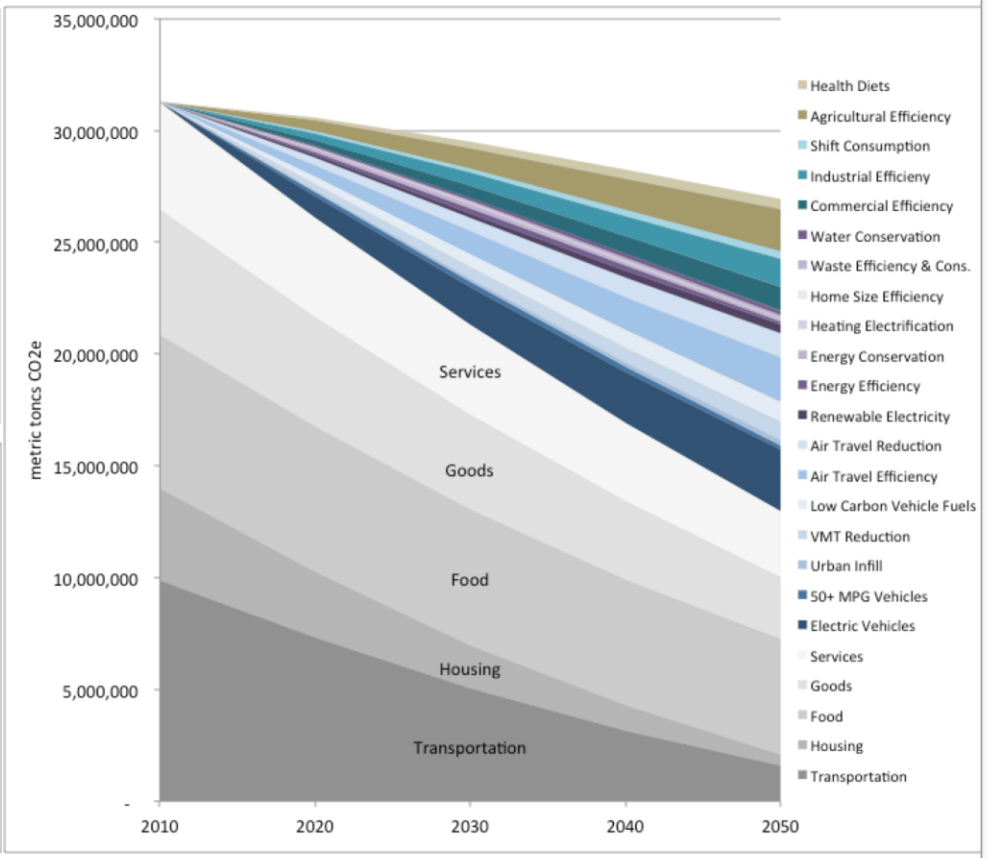
Consumption-based GHG inventory 2010:	31,307,126	tCO2	
Consumption-based GHG inventory 2050:	12,984,477	tCO2	58.5% reduction
Average household carbon footprint 2010:	35.59	tCO2	
Average household carbon footprint 2050:	13.29	tCO2	62.7% reduction











DASHBOARD | Population | Bayarea | CARBON FOOTPRINT | CONSUMPTION | BGDATA | GHG FACTORS | Notes | figures | GOODSSERVICES | FO MODEL

Normal View | Ready | Sum=0

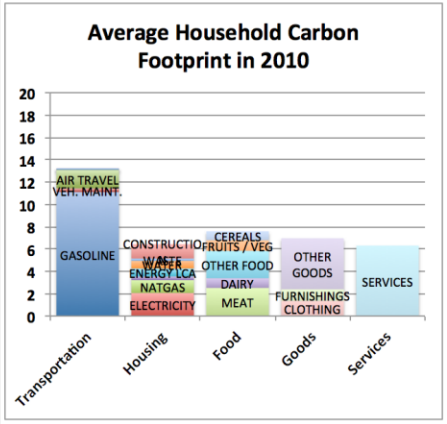
SELECT

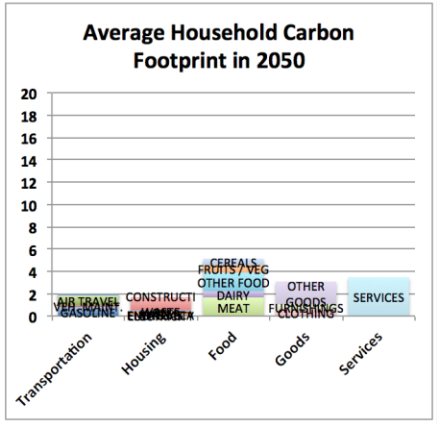
CITY

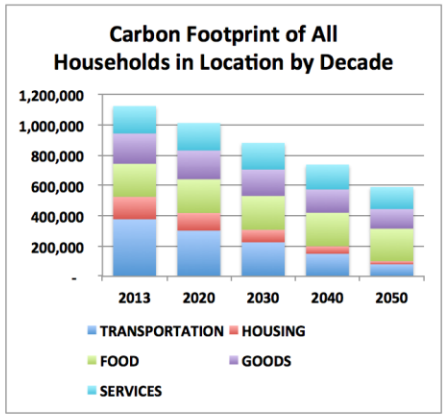
DAVIS

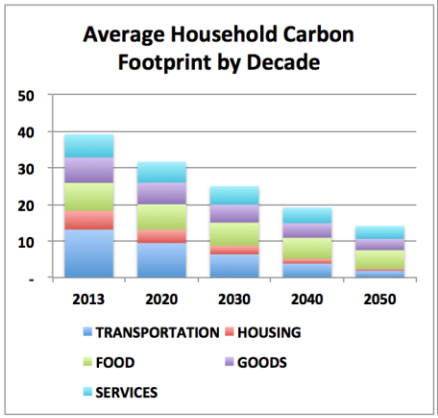
Scenario 6) Max

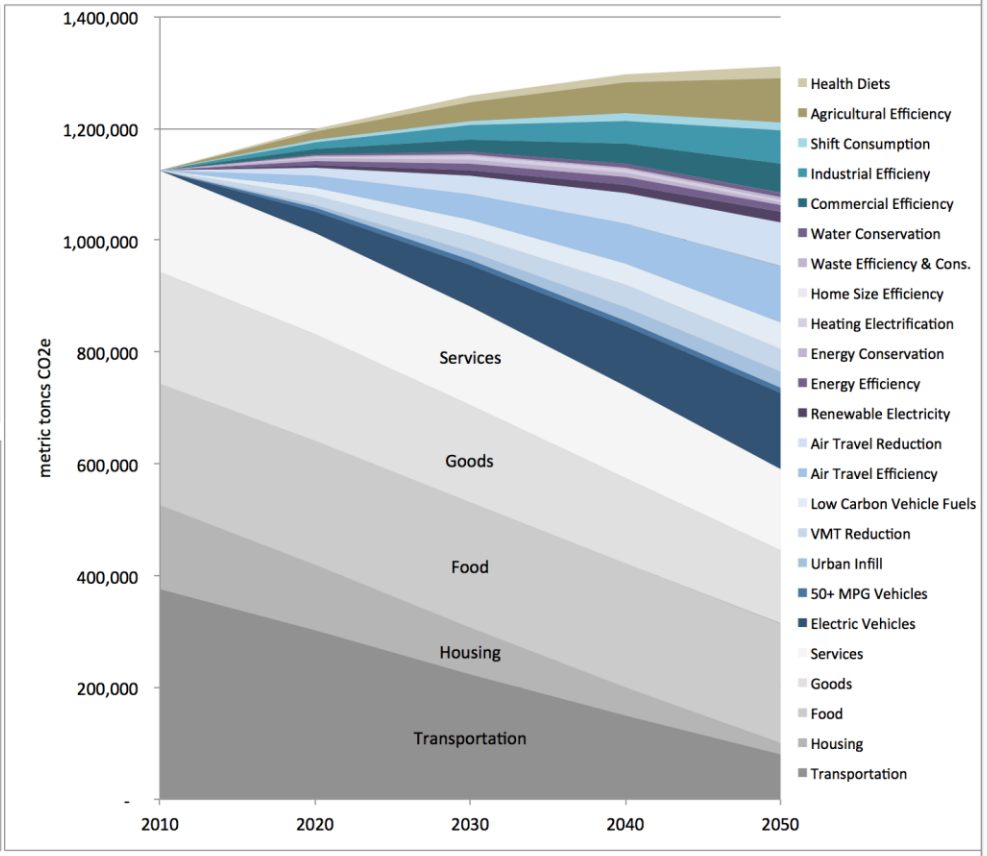
Consumption-based GHG inventory 2010:	1,124,664	tCO2	
Consumption-based GHG inventory 2050:	589,935	tCO2	47.5% reduction
Average household carbon footprint 2010:	39.14	tCO2	
Average household carbon footprint 2050:	14.06	tCO2	64.1% reduction











DASHBOARD | Population | Bayarea | CARBON FOOTPRINT | CONSUMPTION | BGDATA | GHG FACTORS | Notes | figures | GOODSSERVICES | FO MODEL

Normal View | Ready | Sum=0

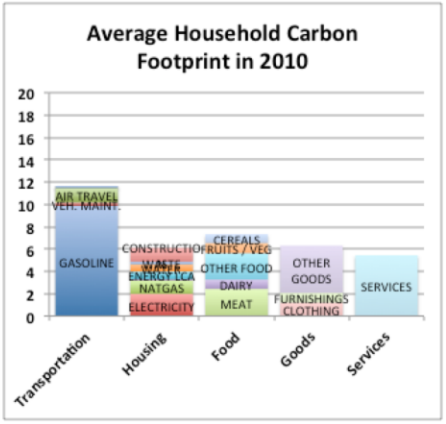
SELECT

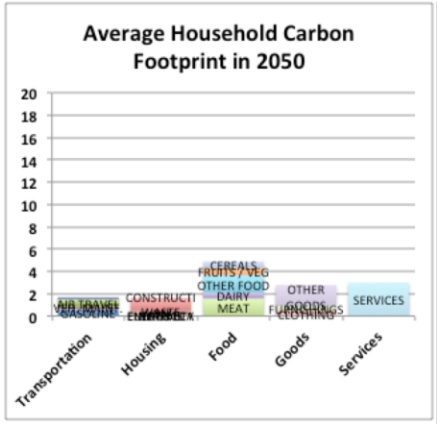
CITY

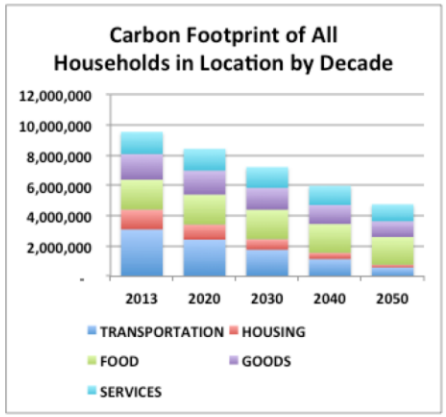
SACRAMENTO

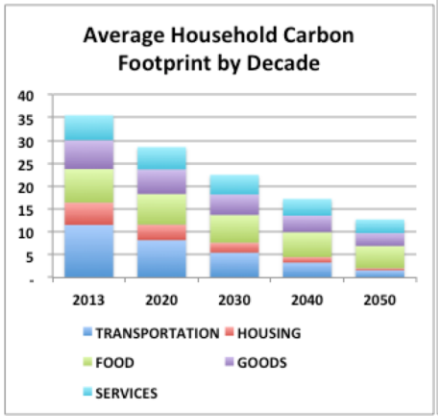
Scenario 6) Max

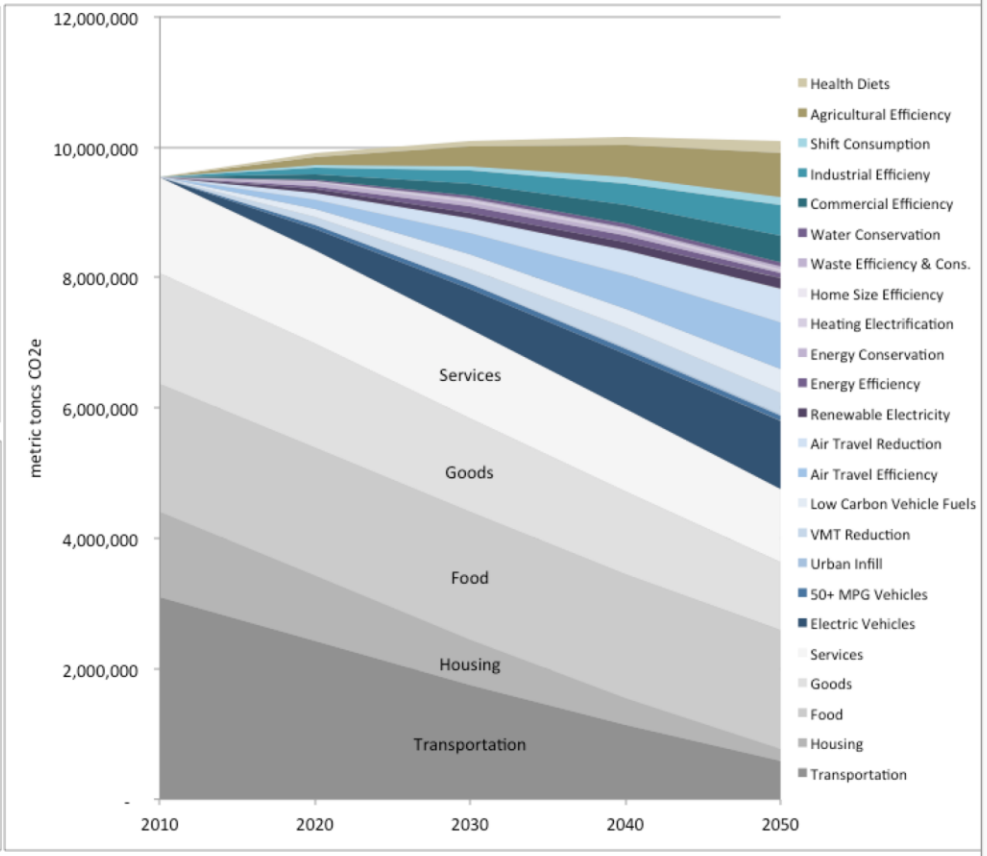
Consumption-based GHG inventory 2010:	9,541,793	tCO2	
Consumption-based GHG inventory 2050:	4,756,944	tCO2	50.1% reduction
Average household carbon footprint 2010:	35.46	tCO2	
Average household carbon footprint 2050:	12.69	tCO2	64.2% reduction











DASHBOARD | Population | Bayarea | CARBON FOOTPRINT | CONSUMPTION | BGDATA | GHG FACTORS | Notes | figures | GOODSSERVICES | FO MODEL

Normal View | Ready | Sum=0

Relevance for EE Potential Studies:

1. Proposed Efficiency Method: 20% achievable potential; 30% technical potential efficiency for electricity in SF Bay Area

2. Carbon footprints (incl. energy) and mitigation potential vary widely by location

3. More work on EE and CF potential is needed for other locations

1. Important to consider full lifecycle impacts in decisions

2. Optimal EE strategy is not necessarily the optimal GHG strategy
    1. Example: ZNE ≠ ZNC
    2. RE is cheaper and easier than many EE measures….important to consider alternatives to EE. Implication: limit potential to cost-effective vs. RE?
    3. Incremental improvements in EE may prevent meeting long-term GHG reduction targets – e.g., need to phase out natural gas

Comments?

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Results

- Total GHG emissions (530M tCO2e) are 16% higher than the production-based perspective in 2010 (which was 456M tCO2e)
- Food becomes the largest portion of carbon footprints by 2035 (also services due to shifting spending on goods to services)
- 50% GHG reduction in absolute terms is the max possible under the most aggressive scenario for 2050 for CA (from the consumption perspective)
- Cities in the Central Valley experiencing population boom (e.g., Bakersfield will grow by 90%) can only reduce by 30% (and 0% reduction in the Medium scenario)
- Some cities are expected to decrease in population, making deeper reductions much more feasible
- Air travel becomes a larger share of emissions, but holds large potential for deep reductions using advanced biofuels (plus efficient design)
- Conservation reduces up to 15% GHG reduction in 2050, but its contribution is minimal in 2050 if technology is primarily renewable.
- High-Speed Rail reduces total emissions by less than 0.5%, but contributes to urban infill which has potential for 0 - 10% reduction depending on the location
- Urban infill has higher potential in SF Bay Area where public transit access reduces car dependency.

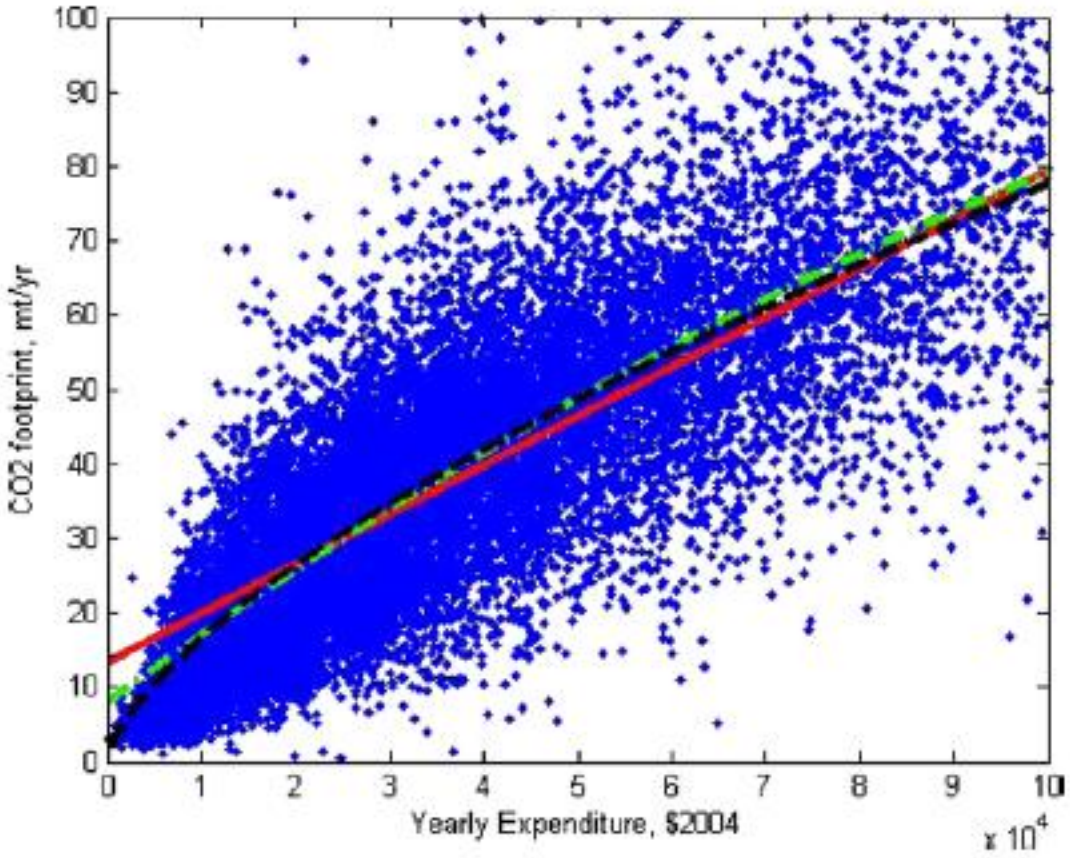
Policy Implications

- An increasing share of California's carbon footprint will occur outside the geographic boundaries
- Local governments and the state should incorporate consumption-based emissions and targets
- Local governments should consider adopting per capita targets
- The mix of GHG mitigation opportunities depends on the target. California's 2030 target calls for a mix of urban infill, technology and conservation. California's 2050 target would focus on technology
- Near complete electrification of vehicles and heating with renewable electricity is needed to meet most aggressive scenarios (e.g., California's 2050 target)
- California should set 50% GHG reduction target by 2050 from consumption perspective. This would send strong single internationally.
- Method creates emissions and migration scenarios for every CA city and county, with maps at neighborhood scale. Can be readily scaled up to all of US and internationally.
- Public transportation infrastructure similar to the SF Bay Area would be needed in the Central Valley in order realize the full benefits of urban infill

Future work

- Deep dive paper comparing cities, land use
- Method to compare production-based and consumption-based emissions
- Develop scenarios for policies under local, regional and state control
- Include cost of measures, and individual policies supporting each area of reductions
- Deep dive on feasible reduction under local, regional and state policies
- Cost of 50% reduction to state government, municipalities, regions, households
- Run least-cost optimization for policies under control by each location
- Develop online tool (current spreadsheet tool is set up to make this easy)

Distribution of U.S. household carbon footprints



Weber, C.L., & Matthews, H.S., Quantifying the global and distributional aspects of American household carbon footprint. *Ecological Economics S 6 6 (2 0 0 8) 3 7 9 – 3 9 1*

#	POLICIES	Selected Scenario	SCENARIOS										
		Scenario 2) SB375	Scenario 1) BAU	Scenario 2) SB375	Scenario 3) SB375 +	Scenario 4) High Tech	5) Conserve	Scenario 6) Max	Scenario 7) Med.	Scenario 8) Low	Scenario 9) HSR	Scenario 10) HSR+	Custom
	SMART GROWTH												
	Urban Infill	67%	10%	67%	77%	10%	10%	77%	50%	25%	0%	5%	0%
1	SB375 (state, local)	67%	10%	67%	67%	10%	10%	67%	50%	25%	0%	5%	
2	SB375+ (local)	0%			10%			10%					
	Home Size (new)	0%	0%	0%	20%	0%	0%	20%	10%	5%	0%	0%	0%
3	Tax shift (local)	0%			20%			20%	10%	5%			
	TECHNOLOGY												
	Electric Vehicles	0%	0%	0%	0%	70%	0%	70%	45%	30%	0%	0%	0%
4	Incentives (state)	0%				50%		50%	40%	30%			
5	Charging infrastructure (state, local)	0%				10%		10%	5%				
6	Behavior campaigns (local)	0%				10%		10%					
	50+ MPG Vehicles	25%	25%	25%	25%	30%	0%	30%	20%	15%	25%	25%	0%
7	Incentives (state)	25%	25%	25%	25%	30%		30%	20%	15%	25%	25%	
8	Behavior campaigns (local)	0%											
	Renewable Electricity	60%	60%	60%	60%	100%	60%	100%	85%	60%	60%	60%	0%
9	RPS (state)	50%	50%	50%	50%	80%	50%	80%	70%	50%	50%	50%	
10	Distributed generation (local)	10%	10%	10%	10%	20%	10%	20%	15%	10%	10%	10%	
	Heating Electrification (new)	0%	0%	0%	0%	100%	0%	100%	50%	25%	0%	0%	0%
11	Building codes (state, local)	0%	0%			100%		100%	50%	25%			
	Heating Electrification (existing)	0%	0%	0%	0%	100%	0%	100%	50%	25%	0%	0%	0%
12	Building codes (state, local)	0%				100%		100%	50%	25%			
	Energy Efficiency (new)	30%	30%	30%	30%	50%	30%	100%	100%	100%	30%	30%	0%
13	Building codes (state, local)	30%	30%	30%	30%	50%	30%	100%	100%	100%	30%	30%	
	Energy Efficiency (existing)	20%	20%	20%	20%	50%	20%	40%	40%	30%	20%	20%	0%
14	Incentives (state)	20%	20%	20%	20%	40%	20%	40%	40%	30%	20%	20%	
15	Retrofit programs (state, local)	0%				10%							
	Low Carbon Fuels	10%	10%	10%	10%	30%	10%	30%	20%	15%	10%	10%	0%
16	LCFS (state)	10%	10%	10%	10%	30%	10%	30%	20%	15%	10%	10%	
	Air Travel Efficiency	0%	0%	0%	0%	40%	0%	40%	25%	10%	0%	0%	0%
17	Biofuels	0%	0%	0%	0%	30%		30%	20%	10%			
18	Lightweighting	0%				10%		10%	5%				
	Commercial Efficiency	30%	30%	30%	30%	30%	50%	30%	50%	40%	30%	30%	30%
20	Building codes (state, local)	30%	30%	30%	30%	30%	50%	30%	50%	40%	30%	30%	30%
	Waste Efficiency	0%	0%	0%	0%	40%	0%	40%	20%	5%	0%	0%	0%
21	Waste to energy (local)	0%				20%		20%	10%	5%			
22	Waste stream efficiency (local)	0%				20%		20%	10%				
	Industrial Efficiency	30%	30%	30%	30%	30%	30%	50%	40%	35%	30%	30%	30%
23	Cap-n-trade (state)	30%	30%	30%	30%	30%	30%	50%	40%	35%	30%	30%	30%
	Agricultural Efficiency	5%	5%	5%	5%	30%	10%	30%	20%	10%	5%	5%	5%
24	Incentives (state)	5%	5%	5%	5%	30%	10%	30%	20%	10%	5%	5%	5%
	Reducd Consumption												
	VMT Reduction	5%	0%	5%	5%	0%	20%	10%	0%	0%	3%	3%	10%

	Renewable Electricity	60%	60%	60%	60%	100%	60%	100%	85%	60%	60%	60%	0%
9	RPS (state)	50%	50%	50%	50%	80%	50%	80%	70%	50%	50%	50%	
10	Distributed generation (local)	10%	10%	10%	10%	20%	10%	20%	15%	10%	10%	10%	
	Heating Electrification (new)	0%	0%	0%	0%	100%	0%	100%	50%	25%	0%	0%	0%
11	Building codes (state, local)	0%	0%			100%		100%	50%	25%			
	Heating Electrification (existing)	0%	0%	0%	0%	100%	0%	100%	50%	25%	0%	0%	0%
12	Building codes (state, local)	0%				100%		100%	50%	25%			
	Energy Efficiency (new)	30%	30%	30%	30%	50%	30%	100%	100%	100%	30%	30%	0%
13	Building codes (state, local)	30%	30%	30%	30%	50%	30%	100%	100%	100%	30%	30%	
	Energy Efficiency (existing)	20%	20%	20%	20%	50%	20%	40%	40%	30%	20%	20%	0%
14	Incentives (state)	20%	20%	20%	20%	40%	20%	40%	40%	30%	20%	20%	
15	Retrofit programs (state, local)	0%				10%							
	Low Carbon Fuels	10%	10%	10%	10%	30%	10%	30%	20%	15%	10%	10%	0%
16	LCFS (state)	10%	10%	10%	10%	30%	10%	30%	20%	15%	10%	10%	
	Air Travel Efficiency	0%	0%	0%	0%	40%	0%	40%	25%	10%	0%	0%	0%
17	Biofuels	0%	0%	0%	0%	30%		30%	20%	10%			
18	Lightweighting	0%				10%		10%	5%				
	Commercial Efficiency	30%	30%	30%	30%	30%	50%	30%	50%	40%	30%	30%	30%
20	Building codes (state, local)	30%	30%	30%	30%	30%	50%	30%	50%	40%	30%	30%	30%
	Waste Efficiency	0%	0%	0%	0%	40%	0%	40%	20%	5%	0%	0%	0%
21	Waste to energy (local)	0%				20%		20%	10%	5%			
22	Waste stream efficiency (local)	0%				20%		20%	10%				
	Industrial Efficiency	30%	30%	30%	30%	30%	30%	50%	40%	35%	30%	30%	30%
23	Cap-n-trade (state)	30%	30%	30%	30%	30%	30%	50%	40%	35%	30%	30%	30%
	Agricultural Efficiency	5%	5%	5%	5%	30%	10%	30%	20%	10%	5%	5%	5%
24	Incentives (state)	5%	5%	5%	5%	30%	10%	30%	20%	10%	5%	5%	5%
	Reducd Consumption												
	VMT Reduction	5%	0%	5%	5%	0%	20%	10%	0%	0%	3%	3%	10%
25	HSR (state)	5%		5%	5%		5%	5%	0%	0%	3%	3%	10%
26	Public transit (local)	0%					10%	5%					
27	Biking, walking, etc. (local)	0%					5%						
	Air Travel Reduction	5%	0%	5%	5%	0%	15%	15%	10%	5%	5%	5%	0%
28	HSR (state)	5%		5%	5%		5%	5%	5%	5%	5%	5%	
29	Other (local)	0%					10%	10%	5%				
	Energy Conservation	0%	0%	0%	0%	0%	25%	25%	15%	10%	0%	0%	0%
29	Behavior campaigns (local)	0%					25%	25%	15%	10%			
	Shift Consumption	0%	0%	0%	0%	0%	25%	25%	15%	10%	0%	0%	0%
30	Behavior campaigns (local)	0%					25%	25%	15%	10%			
	Healthy Diets	0%	0%	0%	0%	0%	10%	10%	5%	0%	0%	0%	0%
31	Behavior campaigns (local)	0%					10%	10%	5%	0%			
32	Schools (local)	0%					5%	5%					
	Waste Conversion	0%	0%	0%	0%	0%	30%	30%	20%	10%	0%	0%	0%
33	Behavior campaigns (local)	0%					30%	30%	20%	10%			
	Water Conservation	0%	0%	0%	0%	0%	30%	30%	20%	10%	0%	0%	0%
34	Behavior campaigns (local)	0%					30%	30%	20%	10%			
	Taxation	0%	0%	0%	0%	0%	15%	15%	10%	5%	0%	0%	0%
35	Carbon tax (state, local)	0%					15%	15%	10%	5%			
36	Carbon offsets (local)	0%											

The BIG Problem

Climate change is the result of countless daily actions by billions of people embedded in a massive global economy, governed by laws, economic and social forces that influence their actions.

A Smaller Solvable Problem

Those interested in addressing their impact on climate change typically lack understanding of the best opportunities and the potential consequences of those actions.

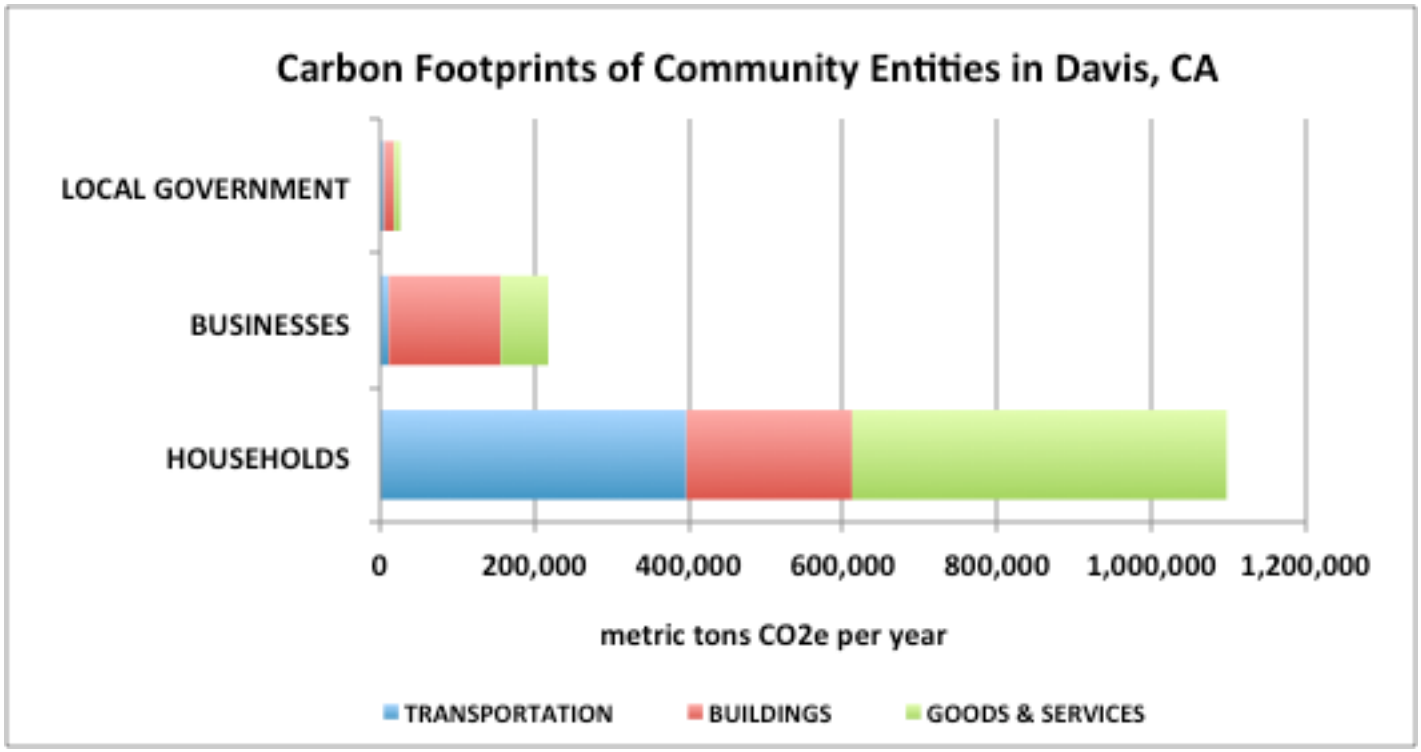
CoolClimate Vision

Smart Tools for a Cooler Planet

CoolClimate's envisions a world in which every national, state and local government, business, organization and household has access (and exposure) to *smart* greenhouse gas decision-making tools, policies and programs.

Smart tools:

- instantly provide usable information,
- are elegantly designed to be user-friendly and esthetically appealing,
- learn from interactions with other users,
- utilize insights from behavioral sciences to motivate users to take action, and
- encourage democratic and participatory decision-making



Source: CoolCalifornia Local Government Decision-support Tool (in review)

California Climate Action Support Tool (CCAST)

RAEL — Renewable & Appropriate Energy Laboratory

California Environmental Protection Agency AIR RESOURCES BOARD

CoolCalifornia.org — Simple steps for a sustainable future

Introduction:
This tool is intended to help California local governments identify cost-effective and feasible greenhouse gas (GHG) reduction strategies and policies, which can be incorporated into a jurisdiction's climate action plan.

Instructions:
1) Introduction page: Adjust any cells in yellow on the introduction page. "Smart default" values are provided for each all cells in the tool.
2) Review information on supporting tabs and make any desired changes to assumptions for measures.
3) Consult documentation: link to documentation
4) Review results on introduction page

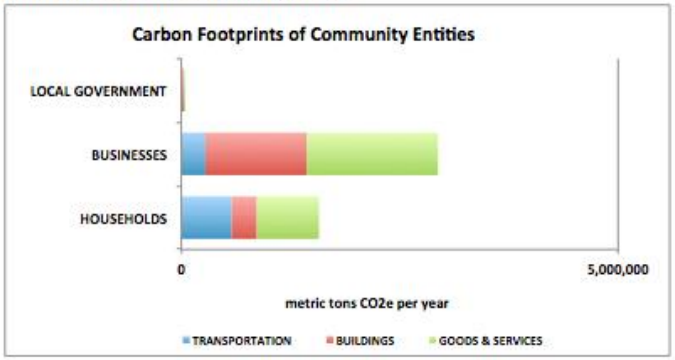
This tool does NOT:
1) Give credit, as defined in a cap and trade program;
2) Assume the greenhouse gas reductions, if implemented, will occur precisely at the value reported with this tool (e.g., if 50 MTCO2E reduction is reported with the tool, the ACTUAL reductions may or may not occur at this value);
3) Give guidance on how to verify emission values reported within this tool. (This work is done by the Local Government Toolkit & Local Government Operations Protocol)
4) Guarantee GHG emission reduction compliance with the California Environmental Quality Act (CEQA).

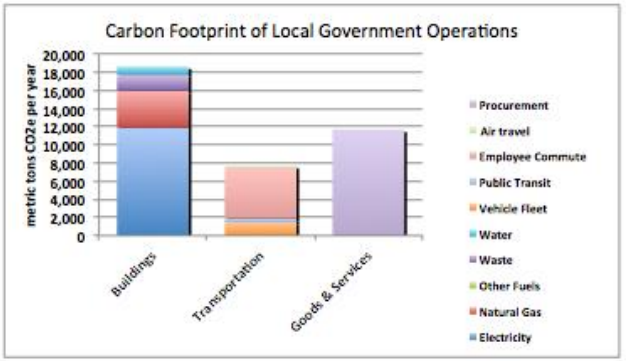
1. Select your County	Example CA County
2. Select your municipality	Example CA City
3. Year of assessment	2012

4. Critical assumptions based on your municipality

Population	100,000	Daytime Electricity Rate ($/kWh)	$0.14	Inflation Rate	3.0%	Community MSW (tons/yr)	96,000
# of Municipal Employees	3,100	Night time Electricity Rate ($/kWh)	$0.12	Electricity Inflation Rate	3.0%	MSW Diversion Rate	55.1%
Sq.ft. of Government Facilities	2,659,000	Residential Nat. Gas Rate ($/kcu.ft.)	$10.12	Natural Gas Inflation Rate	2.0%	Waste Region	Not Applicable
Electric Utility	SMUD	Commercial Nat. Gas Rate ($/kcu.ft.)	$8.44	Gasoline Inflation Rate	3.0%	Air District	SOUTH COAST
Natural Gas Utility	PG&E	Waste Disposal Rate ($/short ton)	$257.73	Nominal Discount Rate (without inflation)	8.0%	Res. Water Rate ($/gallon)	0.0020
Climate Zone	9	Price of Gasoline ($/gallon)	$4.20	Electricity Emissions Factor (tCO2/kWh)	0.000324	Hydro Zone	South Coast
		Price of Diesel ($/gallon)	$4.40			% homes built before 1980	63%

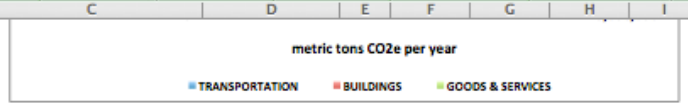
Benchmark Carbon Footprint Results

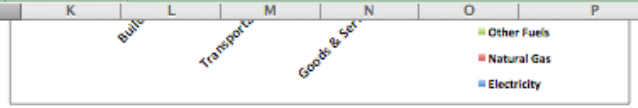




GHG Mitigation Measures Results

	Measure Type	Actor paying upfront cost, Actor receiving savings	Measure	Adoption rate	Lifetime of measure (years)	metric tons CO2e saved over lifetime	Upfront Cost	Annual net savings	Simple payback (years)	Annual Levelized Cost (Savings)	$/metric ton CO2e saved	NPV
1	BUILDING & FACILITIES	Households, Household	Exceed Title 24 for Residential Construction		10	50,544	$5,100,000	$484,045	10.5	-$113,536	-$22	$1,562,800
2	BUILDING & FACILITIES	puchasing policy	Purchase Energy-Efficient Heating		10	3,884	$87,000	$20,160	4.3	-$8,340	-$21	$61,380
3	BUILDING & FACILITIES	puchasing policy	Purchase Energy-Efficient Cooling		10	789	$295,528	$22,704	13.0	$3,061	$39	-$35,115
4	BUILDING & FACILITIES		Install Reflective Roofing		30	183	$178,000	$140,399	1.3	-$127,467	-$20,845	$1,754,567
5	BUILDING & FACILITIES	Local Government	Recommissioning of existing buildings	50%	20	22,014	$398,850	$454,612	0.9	-$422,607	-$384	$5,266,618
6	BUILDING & FACILITIES	puchasing policy	Use Energy-Efficient Computers		10	172	0.0	$20,203	N/A	-$20,203	-$1,172	$156,000
7	BUILDING & FACILITIES	puchasing policy	Use Energy-Efficient Copiers		10	6	0.0	$528	N/A	-$528	-$831	$4,077
8	BUILDING & FACILITIES	puchasing policy	Use Energy-Efficient Printers		10	32	0.0	$3,168	N/A	-$3,168	-$986	$24,464
9	BUILDING & FACILITIES		Replace T12 with T-8 fluorescent lamps		10	1,078	$1,705,711	$495,567	3.4	-$263,816	-$2,447	$1,941,705





GHG Mitigation Measures Results

	Measure Type	Actor paying upfront cost, Actor receiving savings	Measure	Adoption rate	Lifetime of measure (years)	metric tons CO2e saved over lifetime	Upfront Cost	Annual net savings	Simple payback (years)	Annual Levelized Cost (Savings)	$/metric ton CO2e saved	NPV
1	BUILDING & FACILITIES	Households, Household	Exceed Title 24 for Residential Construction		10	50,544	$5,100,000	$484,045	10.5	-$113,536	-$22	$1,562,800
2	BUILDING & FACILITIES	puchasing policy	Purchase Energy-Efficient Heating		10	3,884	$87,000	$20,160	4.3	-$8,340	-$21	$61,380
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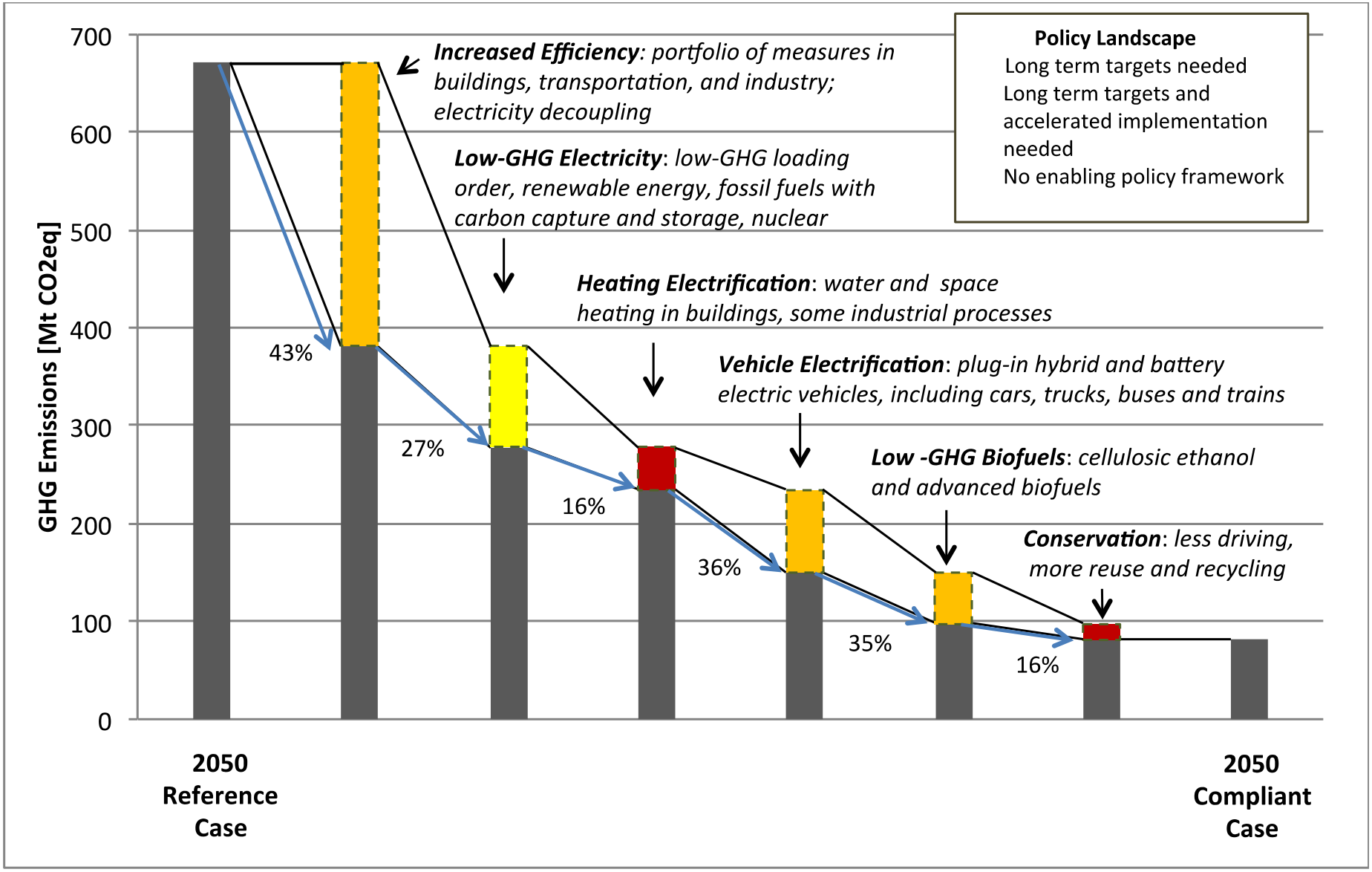
8	BUILDING & FACILITIES	puchasing policy	Use Energy-Efficient Printers		10	32	0.0	$3,168	N/A	-$3,168	-$986	$24,464
9	BUILDING & FACILITIES		Replace T12 with T-8 fluorescent lamps		10	1,078	$1,705,711	$495,567	3.4	-$263,816	-$2,447	$1,941,705
10	BUILDING & FACILITIES		Plant Shade Trees		20	23,283	$8,623,043	$431,152	20.0	$320,644	$275	-$3,677,762
11	BUILDING & FACILITIES		Power management for computers	50%	10	437	$3,968	$17,737	0.2	-$17,198	-$394	$126,578
12	BUILDING & FACILITIES	puchasing policy	Use Energy-Efficient Water Heaters		10	57	7,350.0	$496	14.8	$456	$119	-$3,520
13	BUILDING & FACILITIES		Use LEDs in Exit Signs	100%	16	45	$1,984	$3,399	0.6	-$3,216	-$72	$34,852
14	POWER		Install PV for municipal electricity needs	50%	20	238,776	$18,665,323	$2,579,328	7.2	-$1,081,574	-$2	$13,478,805
15	POWER		Install Solar Water Heaters	10%	15	2,272	$297,217	$14,742	20.2	$13,893	$1	-$113,499
16	SOLID WASTE	School District	Reduce Landfill Waste from Schools		10	1,901	$0	$10,974	N/A	-$10,974	-$58	$84,739
17	SOLID WASTE	Utility, Households	Reduce MSW from Community Actors		10	17,810	$0	$101,879	N/A	-$101,879	-$57	$786,684
18	SOLID WASTE	Utility	Flare Methane		10	406,464	$1,462,000	-$229,000	N/A	$418,336	$10	-$3,230,277
19	SOLID WASTE	Utility	Use Methane from Landfills for Energy		10	82,427	$3,836,329	$2,035,200	1.9	-$1,538,378	-$187	$11,878,946
20	SOLID WASTE	Utility	Upgrade Recycling Facilities		10	162,594	$0	$6,680,304	N/A	-$6,680,304	-$411	$51,583,536
21	SOLID WASTE	Utility, Households	Implement a Pay for Garbage Disposal Ordinance		10	110,583	$1,781,034	$2,754,132	0.6	-$2,523,480	-$228	$19,485,645
22	STREETLIGHTS	Local Government	Reduce Hours of Street Lighting		10	2,444	$215,280	$134,567	1.6	-$106,687	-$437	$823,812
23	STREETLIGHTS	Local Government	Use LED Street Lights		10	5,575	$982,143	$287,520	3.4	-$160,328	-$288	$1,238,012
24	STREETLIGHTS	Local Government	Use LED Traffic Lights		10	367	$22,198	$9,933	2.2	-$7,058	-$192	$54,499
25	STREETLIGHTS	Local Government	Use LED Outdoor Parking Lights & Motion Sensors	50%	10	229	$388,000	$141,775	2.7	-$91,527	-$3,989	$706,751
26	TRANSIT	Local Government	Utilize Alternative Fuels in Vehicles	10%	10	424	$17,200	$6,226	2.8	-$3,998	-$94	$30,874
27	TRANSIT	Local Government	Purchase Electric Cars	10%	10	868	$39,836	$7,888	5.1	-$2,729	-$31	$21,070
28	TRANSIT	Local Government	Purchase More Efficienty (incl. hybrid) Vehicles	20%	10	1,014	$31,869	$12,239	2.6	-$8,112	-$80	$62,639
29	TRANSIT	Local Government	Reduce Air Travel	20%	10	179	$0	$40,169	N/A	-$40,169	-$2,242	$310,178
30	TRANSIT	Local Govt, Employees	Discount Transit	5%	10	739	$11,625	$11,625	1.0	-$10,120	-$137	$78,140
31	TRANSIT	Local Govt, Employees	Support Telecommuting	5%	10	447	$0	$32,867	N/A	-$32,867	-$735	$253,791
32	TRANSIT	Local Government	Properly Maintain tire pressure & oil	50%	10	263	$0	$12,575	N/A	-$12,575	-$478	$97,104
33	TRANSIT	Local Government, Hou	Provide Ride-Sharing Programs	5%	10	954	$31,000	$52,446	0.6	-$48,432	-$508	$373,977
35	WASTEWATER DELIVERY	Utility	Flare Wastewater Methane into CO2		20	363,806	$100,000	-$50,000	-2.0	$58,024	$3	-$723,111
34	WASTEWATER DELIVERY	Utility	Convert the Wastewater Methane into electricity		20	8,170	$264,807	$152,322	1.7	-$131,073	-$321	$1,633,459
36	WATER DELIVERY	Households	Free showerheads and Faucet Aerators	25%	10	14,439	$334,000	$256,000	1.3	-$212,745	-$147	$1,642,764
37	WATER DELIVERY	Local Government	Install Low Flow Toilets	50%	10	27	$13,563	$1,933	7.0	-$177	-$66	$1,367
38	WATER DELIVERY	Local Government	Install Low Flow Faucet Aerators	25%	10	2	271	$171	1.6	-$136	-$574	$1,048
39	WATER DELIVERY	Local Government	Install Water Efficient Landscaping		10	213	930650	$20,976	44.4	$99,547	$4,679	-$768,677
40	WATER DELIVERY	Households	Enact Water Efficient Landscaping Ordinance		10	2,213	$1,607,143	$218,211	7.4	-$10,079	-$46	$77,827

SUMMARY OF RESULTS

SUMMARY BY TYPE				Lifetime of measure	metric tons CO2e saved over lifetime	Upfront Cost	Annual net savings	Simple payback (years)	Annual Levelized Cost ($)	$/metric ton CO2e saved	NPV
BUILDING & FACILITIES				10	102,525	16,401,434	2,094,170	7.8	$350,127	$34	$13,935,889
POWER				10	241,048	18,962,540	2,594,070	7.3	$231,908	$10	$18,616,617
SOLID WASTE				10	781,779	7,079,363	11,353,489	0.6	-$10,298,456	-$132	$157,393,671
STREETLIGHTS				10	8,616	1,607,621	573,795	2.8	-$334,212	-$388	$6,704,699
TRANSIT				10	4,887	131,530	176,036	0.7	-$156,434	-$320	$2,418,626
WASTEWATER DELIVERY				10	371,976	364,807	102,322	3.6	-$47,955	-$1	$1,117,484
WATER DELIVERY				10	16,895	2,885,627	497,292	5.8	-$67,248	-$40	$4,318,423
TOTAL				10	1,527,724	$47,432,923	$17,391,174	2.7	-$10,322,270	-$68	$204,505,409

Previous work focuses on pathways to meet GHG reduction targets not technical or achievable potential



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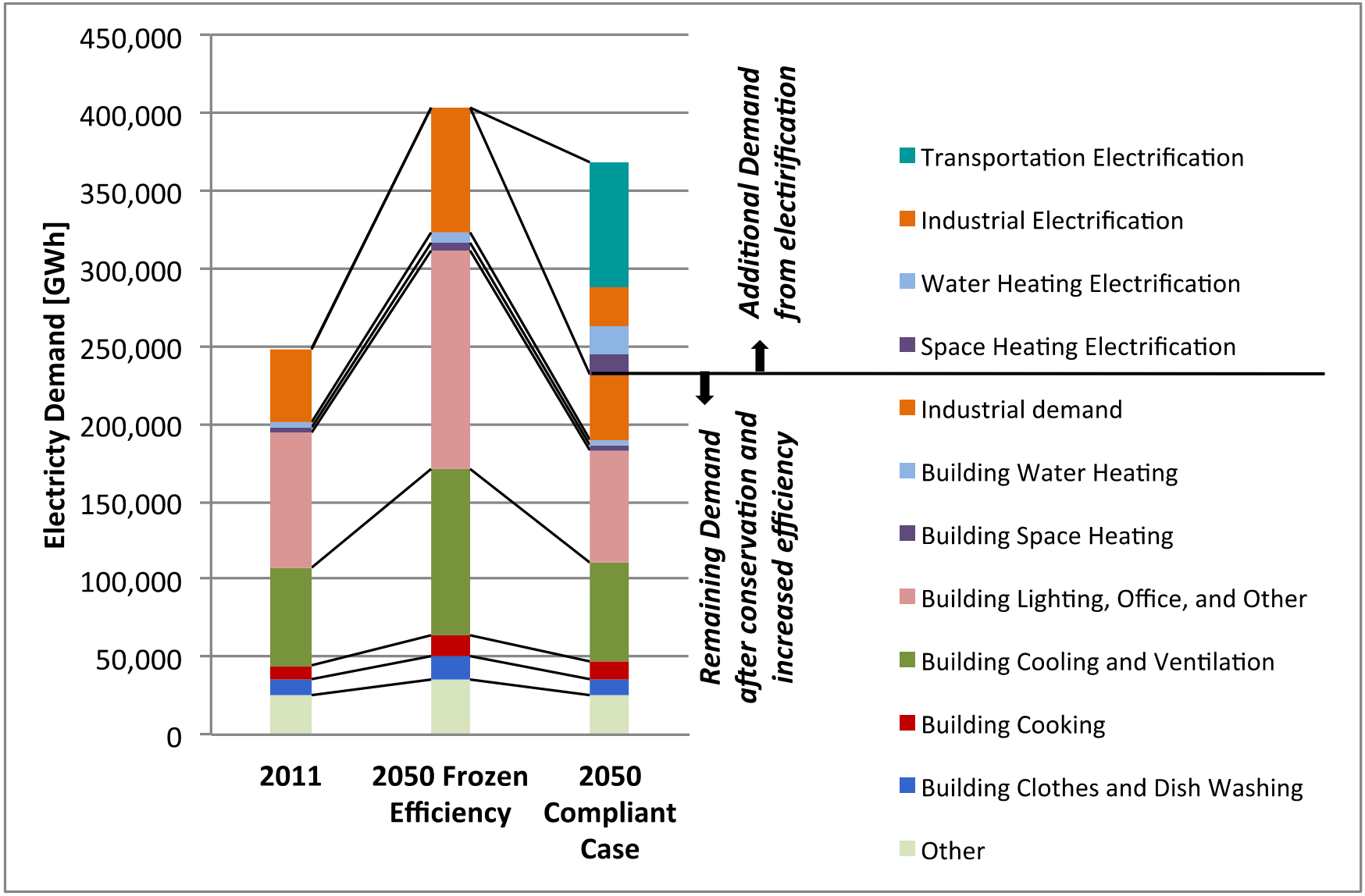

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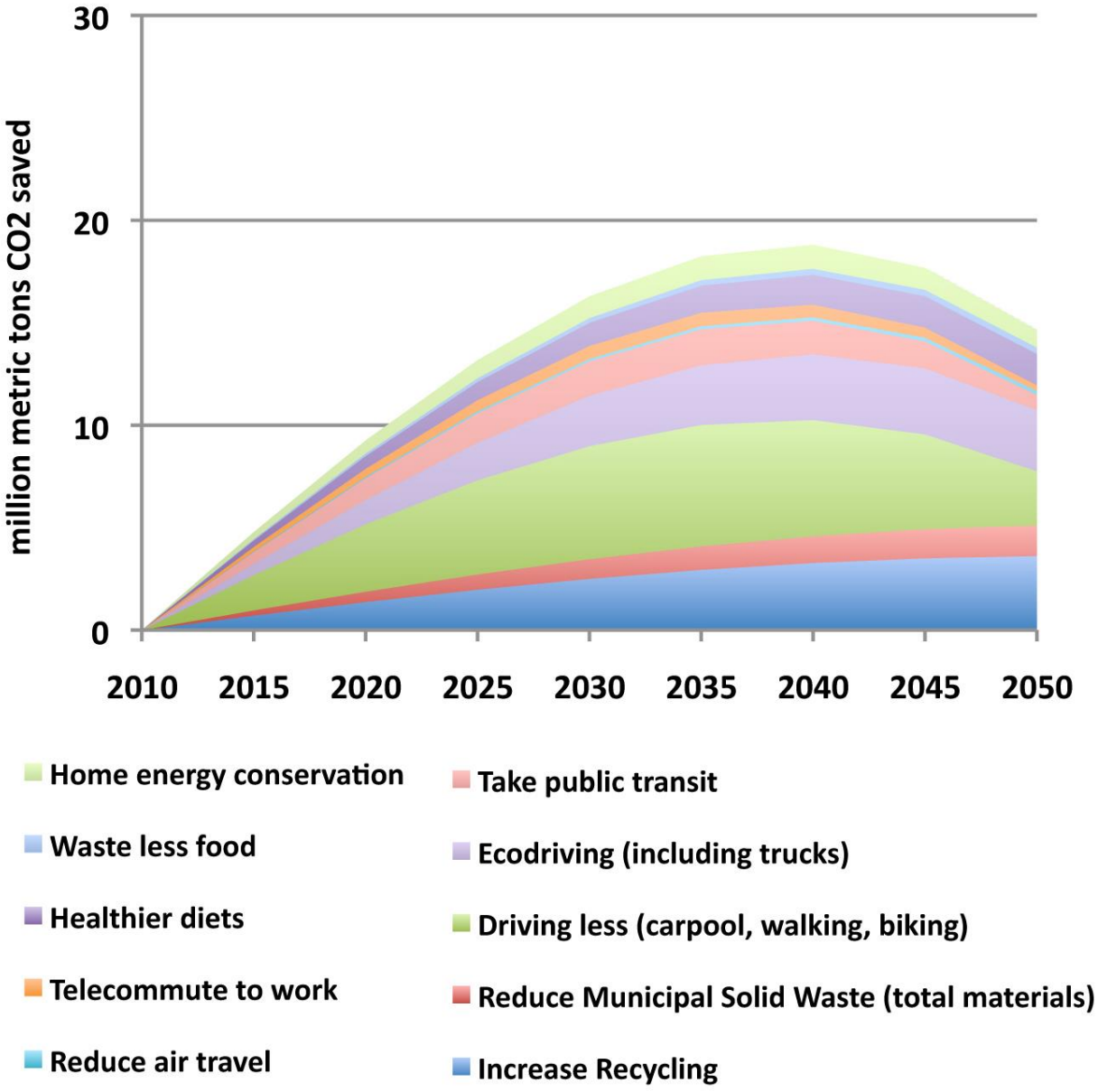
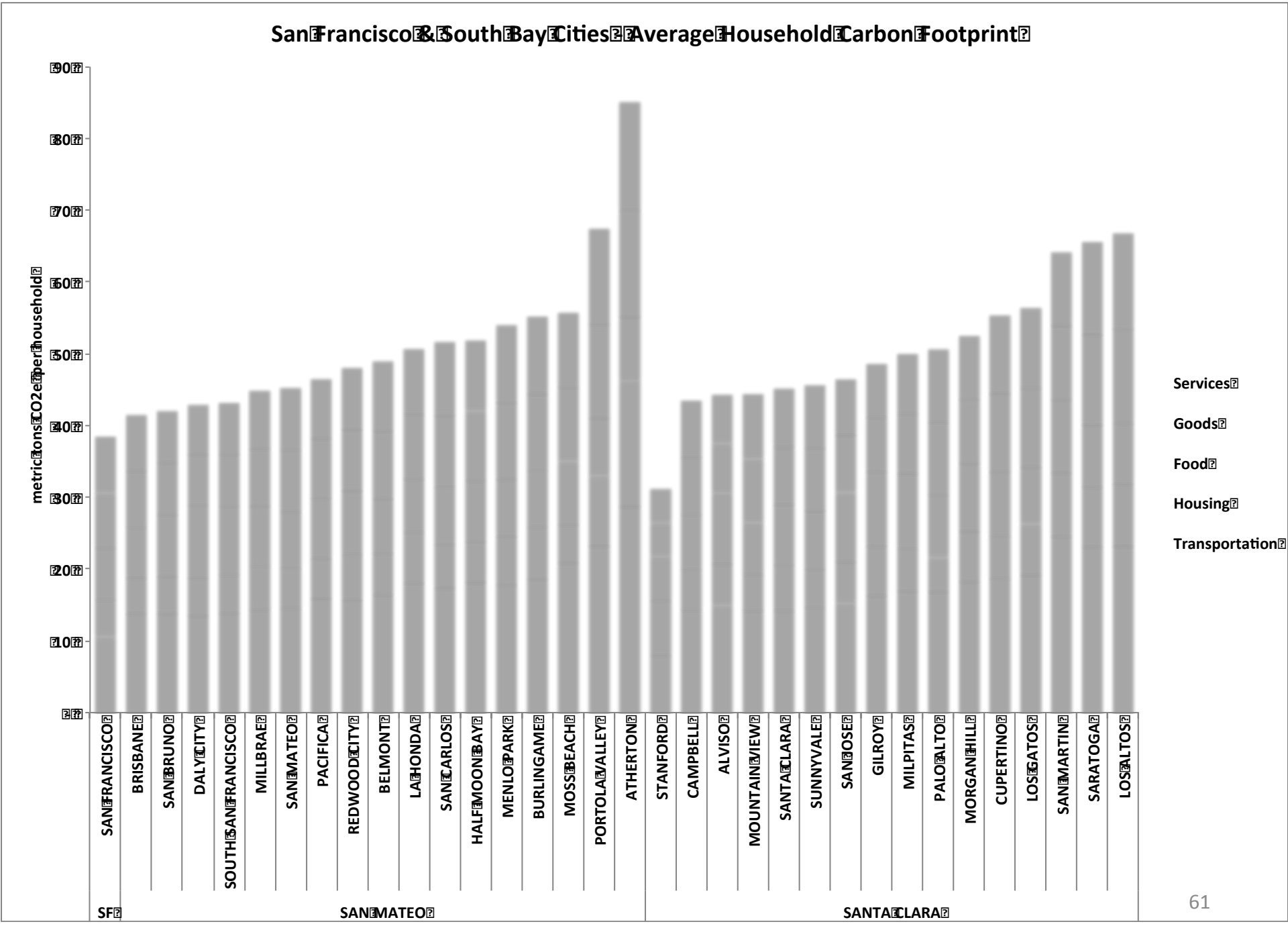
A Behavior Wedge for California households



Wei, M et. al (2011). California's Carbon Challenge: Scenarios for Achieving 80% Emissions Reduction in 2050. White paper prepared for California Energy Commission, *in press*


San Francisco & South Bay Cities Average Household Carbon Footprint
metric tons CO2e per household
90
80
70
60
50
40
30
20
10
0
SAN FRANCISCO
BRISBANE
SAN BRUNO
DALY CITY
SOUTH SAN FRANCISCO
MILLBRAE
SAN MATEO
PACIFICA
REDWOOD CITY
BELMONT
LA HONDA
SAN CARLOS
HALF MOON BAY
MENLO PARK
BURLINGAME
MOSS BEACH
PORTOLA VALLEY
ATHERTON
STANFORD
CAMPBELL
ALVISO
MOUNTAIN VIEW
SANTA CLARA
SUNNYVALE
SAN JOSE
GILROY
MILPITAS
PALO ALTO
MORGAN HILL
CUPERTINO
LOS GATOS
SAN MARTIN
SARATOGA
LOS ALTOS
SF
SAN MATEO
SANTA CLARA
Services
Goods
Food
Housing
Transportation